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Abstract

Two separate subject matter areas, which were felt to represent two distinct types of learning situations, were selected for investigation, namely, a kind of logico-mathematical procedure--the transportation technique, and a visual form discrimination task--aircraft recognition. Two separate courses were developed for each subject matter area. One reflected an inductive instructional approach and the other a deductive method. Each of the four courses was administered to between 55 and 60 Navy enlisted men, and 28 measures of aptitude, interest, and personality variables were obtained on each subject. The most significant finding was the significant second order interaction among all three independent variables. The results of this study strongly support the existence of learning styles and suggests that multi-track instruction based on learning styles might be a cost-effective way of enhancing learning. In the supplementary report preliminary plans were formulated for a study to demonstrate that significant effectiveness gains can be achieved through designing training and to match specific learner characteristics. (AUTHOR)

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STUDY OF TRAINING EQUIPMENT AND INDIVIDUAL DIFFERENCES:

The Effects of Subject Matter Variables

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Study of Training Equipment and Individual Differences: The Effects of Subject Matter Variables

ABSTRACT

This study was the third in a series of research projects aimed at determining whether learning might be enhanced by employing instructional methods which differed in design and use as a function of learner characteristics. Data from the first two studies of this series (Tallmadge & Shearer, 1967) suggested the possibility of a higher order interaction involving the nature of the material to be learned as well as instructional methods and learner characteristics. For this reason, the study described here involved experimental control of three independent variables.

Two separate subject matter areas were selected for investigation which were felt to represent two distinct types of learning situations. The first subject was a kind of logico-mathematical procedure -- the Transportation Technique. The second subject was a visual form discrimination task -- Aircraft Recognition. Two separate courses were developed for each subject matter area. One reflected an inductive instructional approach and the other a deductive method. Each of the four courses was administered to between 55 and 60 Navy enlisted men. Twenty-eight measures of aptitudes, interests, and personality variables were obtained on each subject.

Based on correlation coefficients computed between individual difference measures and examination scores, an unweighted means analysis of variance model was employed to assess the effects of instructional methods, subject matter areas, and interest levels. The most important finding produced by this analysis was the significant ($p<.001$) second order interaction among all three independent variables.

The results of this study strongly supported the existence of learning styles and suggest that multi-track instruction based on learning styles might be a cost-effective way of enhancing learning. Those individual difference measures which interacted with instructional methods and subject matters were all non-cognitive in nature. It would be expected, therefore, that learning styles too might be independent of specific aptitude or ability traits.

Recommendations were made for further research to seek answers to questions regarding subject matter areas and instructional methods as well as learning styles.

FOREWORD

This study is part of a Naval Training Device Center long-range program of applied research on learning, retention and transfer being conducted on both an in-house and contractual basis. The purpose of this project, entitled "Training Equipment and Individual Differences," is to determine whether training efficiency is improved by employing training systems which differ in design and use as a function of differences in characteristics of the trainees.

Two earlier phases of this project were reported in Technical Report NAVTRADEVCEN 66-C-0043-1 by G. K. Tallmadge and J. W. Shearer in March 1967. In that report no interactions were found between trainee aptitudes or interests and method of training. The data suggested, however, that the variable of subject matter content may have interacted with training methods to obscure interactions existing between training methods and trainee characteristics. This led to the present study which introduced the variable of subject matter content into the research design.

The course materials and criterion tests prepared for this study are available for review upon request from either the American Institutes for Research or the Naval Training Device Center.

In the next phase of this project an attempt will be made to extend the generality of the present findings, particularly with the use of individual difference measures found to be useful in this study.

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I. INTRODUCTION

A. Background

In recent years there has been increasing emphasis in educational circles on the development of instructional systems tailored to the needs of individual learners or groups of students who differ in some way from the so-called norm. This emphasis has arisen from a desire as well as a perceived need on the part of educators and training personnel to develop as far as possible whatever capabilities individual students possess. This goal is certainly commendable, but any individualization of instruction must reflect realistic appraisals of both the associated costs and the educational benefits to be gained.

There are definite limits, particularly in military settings, regarding the extent to which instruction can be individualized. There must be some standardization of training programs as it is clearly not possible to provide individually designed and individually conducted instruction for every learner. It is possible, however, to match groups of students with common attributes to appropriate curricula, and there are three ways in which such "matches" can be achieved.

For some time it has been common practice to classify students and trainees on the basis of administered aptitude and (frequently) interest tests. Measures of aptitude level have been used to assign students to courses which differ in terms of intellectual demand. Assignment of individuals to courses of appropriate difficulty levels has been a standard procedure in both military and academic settings for many years and has been very successful in terms of cost-effectiveness considerations at least.

Differential aptitude patterns and interest data have been used in a similar manner to classify students and to assign them to courses encompassing appropriate subject matter content. Although this technique for individualizing instruction has been somewhat less widely employed than the first approach, few would question its effectiveness.

The third "matching" technique is one which has only recently been considered and has not yet been shown to be of practical value. This technique involves classifying students according to their "learning style"* and assigning them to courses employing appropriate instructional methods.

If learning styles exist, it is a logical deduction that training or educational effectiveness might be significantly enhanced through multi-track training employing different instructional methodologies. It was this potential gain which prompted the present study as well as its two predecessors (Angell & Shearer, 1965; Tallmadge & Shearer, 1967).

B. Summary of Relevant Literature

Although the number of research studies specifically concerned with individual differences and training is small, two distinct trends are apparent. The first of these has been the use of programmed instruction as the experimental vehicle, with programmed versus conventional instruction or variations in programming techniques constituting the most frequently employed independent variable. The second apparent trend is the almost exclusive concern given, until very recently, to individual differences in aptitude, as opposed to personality, interest, or motivational factors. Even among studies reflecting these two trends, results have been difficult to interpret.

1. Research on Cognitive Characteristics of Learners

Studies relating instructional method variables to cognitive learner characteristics are difficult to classify. The main reason for this difficulty is that most investigators apparently started out to test simple hypotheses about teaching methods but were subsequently forced to consider other variables when their primary hypotheses were unsupported or when their findings conflicted with other research reports. As a result, these "other variables", although they seem important, have not been systematically investigated and vary so extensively from one study to another that comparisons can only be made on a very tentative basis. For this reason, the organ-

* A "learning style" may be operationally defined as an individual characteristic which interacts with instructional circumstances in such a way as to produce differential learning achievement as a function of these circumstances.

ization of the following pages under the headings of (1) Programmed Instruction Variables, (2) Subject Matter Considerations, and (3) Aptitude Variables is quite arbitrary, and the headings themselves do not adequately describe the summarized studies. Nevertheless, this organization does provide some structure to the discussion.

a. Programmed Instruction Variables

There appears to be a general consensus that appropriately programmed material can improve training effectiveness over conventional instructional methods, although data are far from conclusive (Briggs, Campeau, Gagné, & May, 1967; Schramm, 1964). However, when treatment conditions have been analyzed by ability levels, conventional as well as programmed instruction has been found to interact with learner characteristics.

For example, Reed and Hayman (1962) found that English 2600, a programmed instruction text, was more effective than conventional instruction for high achieving students but inferior to the conventional method for low achieving students. Similarly, Feldman (1965) reported that lower ability children taught reading using conventional materials performed better than those using programmed materials. The results of a study by Goldberg, Dawson, and Barrett (1964) suggested, however, that students with lower mathematical ability do better in a statistics course using programmed methods while those with higher mathematical ability should be taught under conventional classroom instruction. Likewise, Porter (1961), studying IQ differences in relation to methods of spelling instruction, learned that in the second and sixth grades especially, of all IQ/method combinations, the greatest gains were made by low IQ students taught by programmed instruction and the least gains were made by low IQ students receiving conventional instruction.

Interpretations of data are only made more complicated when variations in programming techniques are considered. This is particularly evident when comparing studies of response modes in programmed instruction. In one study data obtained indicated that covert responding facilitated learning for young children of above average intelligence while subjects of average intelligence performed better with programs requiring overt responses (Wittrock, 1963). Two other studies, however, reported exactly the opposite relationship between intelligence level and response mode (Gropper & Lumsdaine, 1961; Lambert, Miller & Wiley, 1962). In still another study, Ashbaugh (1964) found that students of both high and low ability responding covertly performed at least as well as students who responded overtly and spent significantly less time reaching the same level of achievement.

These conflicting findings could have resulted from any of a number of other factors which differed from one study to another, and which have been shown to interact with ability levels. Program step size represents one such possibility. Molstad (1964) found that when step size was varied in a commercial spelling program, high IQ students did best when material was presented in large steps, while lower IQ students achieved best on the version having small steps. On the other hand, results obtained by Shay (1961) indicated that neither condition was significantly better for high IQ students. Low IQ students, however, tended to perform best under small step conditions.

Another factor which could have contributed to the conflicting results is variation in program format. In one of five studies by Campbell (1962) comparing linear with bypassing format, the investigator found that a bypassing program on set theory resulted in significantly better performance than the linear format of the program for students who ranked above the 50th percentile on the Numerical scale of the Differential Aptitude Test. Low ability students, however, achieved equally well on both the linear and the bypass versions of the program. Similarly, results of an investigation by Hartley (1965) indicated that higher ability students profited significantly from instruction under a "skip branching" format but not from the linear version, while for lower ability students neither condition proved significantly better.

Variations in feedback could also have added to the discrepant findings. Kennedy, Turner, and Lindner (1962) reported that although blame caused a significant decrement in the achievement of students with average intelligence, praise as an incentive was unrelated to performance for adolescents of both high and low intelligence. Opposite results, however, were reported in comparable research by Willicut and Kennedy (1963) and Anderson, White, and Wash (1966). These two studies found that both high and low achievers improved when they were praised but not when they were reproofed. The investigation of Van de Riet (1964) also indicated that achievers (non-underachievers) did best when feedback was praise and poorest when feedback was reproof. However, she also found that, unlike achievers, underachievers performed better when reproofed and significantly worse when praised.

In an investigation of a different kind of feedback, Angell and Lumsdaine (1961) obtained data which suggested that a partial-cueing procedure was more effective than an anticipation-with-full correction procedure for slow learners on a meaningful paired-associate task. They found the opposite true for fast learners.

Conflicting results may also have been a consequence of variations in the sequencing of programmed material. Cartwright and Stolurow (cited in Stolurow, 1962), in attempting to teach fractions to mental retardates, reported that Ss learned equally well when materials were organized in either a consecutively sequenced program or in a mixed sequence. However, when aptitude patterns were examined, it was found that scores on the mixed-sequence but not scores on the consecutively-sequenced program were significantly correlated with IQ and total language ability, while scores on the consecutively-sequenced program but not on the mixed-sequence program were significantly correlated with test of arithmetic fundamentals.

Difficulty level of material should also be regarded as a possible source of conflict. Allen (1957) and Lumsdaine and May (1965) reviewed studies relating the difficulty level of material presented by film, the form and the extent of student participation, the ability levels of the learners, as well as the motivation levels. They concluded that although active participation has been found to be most effective for difficult material (most often for the less intelligent, less highly-motivated learner), these findings probably vary as a function of the type of learning involved.

b. Subject Matter Considerations

Quite probably subject matter content is the cause of much discrepancy. In those studies which have sought its effect, subject matter has consistently interacted with both instructional methods and ability variables. This has been quite clearly demonstrated in several studies concerned with the relative effectiveness of televised and conventional instruction for students of varying aptitude levels. Data obtained from these studies showed that lower ability students learned significantly more when taught by conventional instruction than by TV instruction in science (Curry, 1959, 1960; Jacobs & Bollenbacher, 1959) but less when taught by conventional methods in economics and psychology (Dreher & Beatty, 1958) and mathematics problem solving (Jacobs, Bollenbacher, & Keiffer, 1961). On the other hand, high ability learners did significantly better under conventional instruction in English composition (Buckler, 1958) and mathematics (Curry, 1959) but poorer in psychology (Dreher & Beatty, 1958) and in science (Jacobs & Bollenbacher, 1959).

This interactive effect with subject matter is also suggested by the work of Bush, Gregg, Smith, and McBride (1965). In an effort to determine the relationship of aptitude to instructional mode, they concluded that students with relative strength in reading vocabulary are superior to students with relative strength in mathematics fundamentals when both are required to learn from instructional conditions that are highly verbal. On the other hand, students exhibiting relative strength in mathematics fundamentals tend to learn more efficiently in individual laboratory situations than do students showing relative strength in reading vocabulary. Their results, however, also indicated that the subject matter content of the highly verbal instructional conditions tended to be administrative, verbal, and general, while that in the individual laboratory situation was oriented toward hardware, toward science and emphasized precision and calculations. These data suggest, that while the investigators treated aptitude measures in a sound manner, they confounded training method and subject matter in such a way that it was impossible to determine if reported interactions were actually between learner characteristics and training methods or between learner characteristics and course content. The latter alternative appeared, perhaps, more likely.

c. Aptitude Variables

The almost exclusive use of aptitude as the learner characteristic under examination is another possible reason for frequent conflicts among the findings. Furthermore, this variable is most often loosely defined rather than unidimensional or factorially pure. This condition is particularly apparent in studies of the effectiveness of inductive and deductive teaching methods. For example, Colyer (1960) in comparing a guided discovery method of teaching biology with conventional lecture, found that the superiority of the guided discovery method was greater for the low academic achievers than for high academic achievers. In contrast, Orton, McKay and Rainey (1964) reported that while bright and normal students, taught Roman numerals, showed no difference in learning between the rule-example method and the presentation-practice method of instruction, educably mentally handicapped Ss tended toward higher performance if taught by the presentation-practice method. Similarly, Krumboltz and Yabroff (1965) found that while the high-intelligence group made fewer errors in responding to the deductive program, as would be expected, the low intelligence Ss made fewer errors in response to the inductive program. However, these investigators concluded that the two methods were about equally effective in producing accurate transfer of training since no significant interaction appeared between method and intelligence on post-test criterion measures. Nonsignificant results were also reported by Ray (1961) using the inductive and the deductive methods to teach names and functions of parts of micrometers to high and low ability students and by Meconi (1967) using the same methods to teach mathematical concept learning to students of high ability.

Conflicting results are also prevalent in research on auto-instructional methods and aptitude. In one study Bushnell (1963) found that an auto-instructional method of presenting a course in electricity was superior to conventional instruction for students who showed above average knowledge of material on a pretest but not significantly so for below average Ss. In another study (Webb & Baird, 1967) comparing a conventional discussion-lecture method with an independent study method of instruction in a teacher training course, experimental Ss were given a packet containing a list of behavioral objectives, instructions, study guide questions, introductory readings, and worksheets. Analysis of results indicated that for students with the ten lowest grade point averages the experimental condition was superior while for students with the ten highest grade point averages neither method was significantly better. Similar results were reported by Foley (1964) who found a "traditional" course for teaching electronic fundamentals as successful for high aptitude students as an experimental course built around functions of actual equipment, but that the experimental course was more successful in training students of only average aptitude.

A few studies have concentrated on the connection between training methods and more narrowly defined aptitude variables. However, the number of these studies is very small. In one investigation Edgerton (1958) found a significant positive correlation between a word fluency test and achievement in an aircraft familiarization course taught by a "rote" method, but no correlation between the same measures when the course was taught so as to emphasize understanding. Similarly, he found a significant negative relationship between a memory test and achievement in the same course when the course was taught so as to emphasize understanding, but no relationship between these measures when the course was taught by the rote method. In another study, Kress and Gropper (1964) projected programmed materials via television at different rates of presentation, and learned that students who habitually pace themselves slowly in a learning task did best under the slower rate of presentation, while fast self-pacers did best under the fast presentation rate. Investigating the relationship of prior knowledge to training method, Wright, Frederickson, and Claflin (1964) found no difference on a radar detection task criterion test between experienced radar operators, inexperienced trainees having had a special "show and tell" guided course of instruction, and inexperienced trainees having taken a conventional training course involving practice but no guided instruction. Asher (1962), teaching foreign vocabulary, obtained results which indicated that Ss for whom the visual sense mode was dominant learned better if the visual presentation of verbal stimuli preceded oral presentation, while for aurally dominant Ss an aural-visual order of presentation was more effective. Finally Radlow (1955) found that students who learned best under film conditions were high in factors reflecting verbal comprehension, general reasoning ability, and spatial orientation.

2. Research on Non-Cognitive Characteristics of Learners

Until very recently investigations of interactions between personality characteristics and training methods were rarely conducted. In the last few years, however, there has been an effort to analyze the relationship of training methods to two types of personality variables. The first of these encompasses incentive-related factors such as need for achievement and need for social approval, and the other is anxiety level.

a. Incentive Related Factors

Doty and Doty (1964) investigated the relationship between several personality characteristics and success on a commercially prepared programmed instruction unit in physiological psychology. Results of their study indicated that achievement on programmed instruction is significantly related to low sociability needs, but not to achievement need. Woodruff, Faltz, and Wagner (1966) also pursued interactions between a number of personality characteristics and achievement on a programmed unit in biology. However, their findings showed that need to achieve interacted significantly with achievement on programmed instruction. Similarly, Hart (1967) found that in a group of 48 Ss the 24 scoring highest on achievement need learned significantly more under competitive conditions than the 24 lowest scorers.

Hough and Revsin (1963) also tried to determine what characteristics differentiated the high from the low achievers on a programmed unit. They found that neither verbal ability scores nor personality variables (including sociability) related to achievement. On the other hand results of Traweek's study (1964) suggested a significant relation between sociability and achievement on programmed instruction. In his study, students who tended to be more withdrawn and less self-reliant learned fractions far beyond their predicted performance. Lublin (1965), however, reported that students low in autonomy need scored highest on programmed instruction.

Shaver and White (1966) attempted to duplicate the work of Doty and Doty. However, in their study achievement seemed unrelated to any personality variable with the exception of freedom from Anti-Social Tendencies. The authors concluded that further research was needed to establish the extent age level of Ss, the setting in which programmed instruction was utilized, the instruments used to measure personality variables, and the subject matter content of the program affected results of studies dealing with personality characteristics and training methods.

Incentive-associated variables have also been analyzed in relation to variations in feedback. Early research in this area was conducted by Forlano and Axelrod (1937). They found that work achievement of blamed introverts was significantly superior to that of praised introverts or introverts with no incentive. Thompson and Hunnicutt (1944) continuing this area of investigation learned that when introverts and extroverts are grouped together, praise and blame are equally effective in motivating work achievement as compared with no external incentives. In addition, they found that if repeated often enough praise increased performance of introverts until it was significantly higher than that of extroverts who were praised. In the same way, repeated blame increased the performance of the extrovert blame group until it was superior to that of the extrovert praise and introvert blame group. Rim (1965), in an attempt to repeat the earlier findings using the Eysenck Introversion/Extroversion Index, found only that performance of extroverted Ss improved when blamed, as did that of emotionally stable Ss whether praised or blamed.

Although any of the factors already discussed could have accounted for the conflicting results evident in the research of incentive-related variables, it was "subject matter" which affected the relationship of incentive to learning in the studies of Stephens and Michels (1965). These investigators describe a large-scale three-year program of research designed to develop "paper and pencil" measurement techniques for assessing potential "motivatability" of subjects. Need for social approval was investigated along with other incentive variables in relation to a number of different learning tasks. Ss who rated high in need for social approval did better than those who rated low, on both reaction time tasks and verbal paired associated tasks. However, on concept formation tasks need for social approval appeared unrelated.

b. Anxiety Levels

Stephens and Michels (1965) also studied the effect of anxiety on various learning tasks under examination. They found no relationship between anxiety and the learning of verbal paired associates. However, in a concept formation task, high-anxious Ss made more critical errors than low-anxious Ss, and in simple and complex reaction time tasks, high-anxious Ss were found to be slower and to make more errors than low-anxious Ss. In contrast Traweek (1964) obtained data indicating that high test anxiety, rather than hindering Ss, seemed a characteristic of successful learners under programmed instruction.

In another study comparing the effectiveness of two different sequences of material, Moore, Smith, and Teevan (1965) found that low-anxious, low-achieving Ss learned better when materials were sequenced in an easy-to-difficult order, while high-anxious, high-achieving Ss did better with materials presented in a difficult-to-easy sequence.

Grimes and Allensmith (1961) investigated two methods of primary reading instruction -- a structured phonics program and a less structured whole-word approach -- in relation to anxiety and compulsivity. They found, as they had expected, that highly anxious, highly compulsive children did better under the structured method than they performed under the unstructured method.

A number of studies have investigated the effect of various forms of feedback on anxiety. Campeau (1965) found that female Ss high in anxiety did better when feedback was provided than when it was not provided, while those low in anxiety did better when feedback was not provided than when it was. However, the study of Ishiguro (1965) indicated that recall of high-anxious students increased under conditions of no feedback, but would decrease if feedback consisted of information about failure and personal reproach. On the other hand, low-anxious Ss recalled most when informed of failure. In another study, Horowitz and Armentrout (1965) found that high-anxious Ss performed better when reinforcement was verbal response than when a buzzer informed them of their performance. Low-anxious Ss tended to do equally well under either reinforcement condition.

3. Research to Identify Learning Styles

Certainly one of the most thorough investigations of learning styles conducted so far was that of Snow, Tiffin, and Siebert (1965). Unlike most of the studies already reviewed, which sought interactions between one kind of learner characteristic and the treatment conditions, these investigators tried to determine how selected attitude, personality, past experience, and aptitude variables related differentially to learner performance under different methods of teaching the same subject matter. Comparing live with filmed demonstrations of physics experiments, they found that students high in ascendancy and students low in responsibility performed better under live conditions than similar students assigned to film conditions. Conversely, students low in ascendancy and students high in responsibility tended, though not significantly, toward better performance under film conditions. When only students with little or no previous knowledge of physics were considered, those with unfavorable attitudes toward instructional films and those with high numerical aptitude achieved higher scores if taught under live conditions, while those with favorable attitudes toward films tended toward higher achievement after filmed demonstrations. Students with low numerical aptitude and a substantial previous knowledge of physics achieved, although not significantly, higher scores when in the film group. Live presentations appeared more appropriate for students with high verbal aptitude and some previous knowledge. Students with extensive entertainment film experience and those with past library film experience performed significantly better with the film presentation.

In an equally thorough exploratory study, Tallmadge and Shearer (1967) found no evidence to support the existence of learning styles when they contrasted an "understanding" with a "rote memorization of procedures" training method for presenting a one week segment of the U.S. Navy Radarman Class A School curriculum. These investigators suggested that the most plausible cause of their negative findings was the heterogeneity of the subject matter used as the experimental vehicle for their study. The suggestion was made that existing relationships between learner characteristics and instructional methods might have reversed with changes in the nature of the material to be learned in the experimental course. If correct, this explanation would account for their negative findings since the nature of the criterion measure they employed did not permit separate analysis of the individual components of the learning task.

C. Problem Statement

It is clear from the preceding literature review that little conclusive evidence exists to support any theory regarding training methods and individual differences. For the most part, results have been ambiguous, impossible to replicate, and discrepant with results of similar studies. However, what does seem apparent at this time is that a large number of variables exist which not only influence training effectiveness, but also interact with individual differences and with each other in such complex combinations that a thorough understanding of their interrelationships is unlikely to be achieved in a single study.

It is felt that research in this area is still in the exploratory stages and should be clearly acknowledged as such. One clear implication of this situation is that the fruitfulness and potential value of research in the area of individual differences and training is likely to be directly related to the number of variables which can be examined simultaneously and to the rigor exercised in defining and controlling those factors which are not manipulated. Studies are needed which look not for simple effects, or even first order interactions but rather for a definition of the more complex interactions which are known to exist.

II. METHOD

This study was the third in a series of research projects aimed at determining whether learning might be enhanced by employing instructional methods which differed in design and use as a function of learner characteristics.

The basic approach for this study was largely suggested by the results of the first two studies of this series (Tallmadge & Shearer, 1967). These studies found no significant interactions between instructional methods and learner characteristics, but did suggest the possibility of a higher order interaction involving the nature of the material to be learned as well as instructional methods and learner characteristics. The present research was designed to consider these three experimental variables simultaneously.

A. Assessment of Learner Characteristics

Learner characteristics have most commonly been studied with respect to the content or difficulty level of instruction. The present study, however, was concerned with the issue of learner characteristics which relate to the method, rather than the content, of instruction. Content was predicted to act as a "moderator variable" (Guion, 1967, pp. 202-204) which would affect the magnitude or direction of the relationship between learner characteristics and instructional methods.

Individual characteristics which interact with instructional circumstances in such a way that they enhance learning under one set of circumstances and impede learning under a different set of circumstances have been popularly called learning styles. This operational definition initially prompted project personnel to search for learning styles by trying out various instructional methods and looking to see who did best under each condition. Those who learned most efficiently under "Instructional Method A" could then be said to possess a "Type A" learning style, etc. Further thinking about this approach, however, revealed some basic flaws.

Instruction cannot exist without some content, nor can content which is taught be completely "erased" from the learner's memory. For these reasons, it is clearly not possible to teach the same content to the same

Ss more than once (as would be required to test different instructional methods) without seriously contaminating the experimental results. The implication of this conclusion is that the tryout of different instructional methods on single Ss or groups of Ss requires that the content which is taught also be different.

While it would be perfectly feasible to teach groups of Ss a number of separate "courses", each of which covered a different topic and employed a different instructional method, it would no longer be possible to determine whether a S's achievement was related to the instructional method or to the content of the courses, or both. This, in fact, was exactly the problem encountered by Bush et al., (1965) in the study cited earlier. In view of these several factors, it did not appear feasible to identify learning styles through observation of performance following experimentally controlled learning experiences.

The only other approach which appeared promising was to collect a large amount of psychological test data on the experimental Ss and attempt to identify relationships between these measures and learning achievement which differed as a function of instructional method. This approach was ultimately adopted and the following battery of tests was selected:

- Kuder Vocational Preference Record
- Gordon Personal Profile
- Short Employment Test - Verbal
- Short Employment Test - Numerical
- Finding A's Test
- Letter Sets Test
- Picture - Number Test
- First and Last Names Test
- Figure Classification Test
- Inference Test
- Locations Test
- Identical Pictures Test
- Logical Reasoning Test

Because Navy enlisted men served as Ss for the research, scores were also obtained for the four tests comprising the Navy Basic Battery -- a

General Classification Test, an Arithmetic Test, a Mechanical Test, and a Clerical Test.

The Kuder test was selected primarily because it had shown promising results in the Phase II study (Tallmadge & Shearer, 1967) where several scales were found to produce interactions with instructional methods which approached statistical significance. Other reasons for its selection were (1) its "level" appeared appropriate for the typical Navy enlisted man and (2) its scales were generic rather than job-specific and could thus be more readily interpreted.

The Gordon Personal Profile was selected because it was found to identify student characteristics which interacted with instructional <u>media</u> in one of the few studies in this field which was well controlled and produced significant results (Snow et al., 1965).

The two Short Employment Tests were selected to compliment the Basic Battery measures in their respective areas and because of their brevity and reported high quality (Buros, 1965).

The remaining tests in the battery were all selected from the Kit of Reference Tests for Cognitive Factors (French, Ekstrom, & Price, 1963). Had time permitted, this entire battery might have been administered. Since the required time was not available, specific tests were selected to represent those "factors" which appeared most directly related to the instructional methods selected for investigation and to the selected subject matter areas. The factors represented by these tests were: (1) Induction, (2) Associative (Rote) Memory, (3) Perceptual Speed, and (4) Syllogistic Reasoning.

B. Selection of Topics to be Taught

Several criteria were established for selection of the courses to be developed and taught experimentally. Since budget and time restrictions would not permit experimentation with more than a small number of courses, it was desirable to have them as different as possible in terms of content. It was also considered important that the content of each course be as homogeneous as possible.

A third criterion related to the selection of courses was that they should be relevant to Navy training programs. It was not considered essential that the content taught be identical to segments of existing Navy programs. It was felt, however, that sufficient similarity should be provided to permit the study findings to be generalized to Navy applications.

Four additional criteria were generated as a result of practical considerations: (1) the selected courses had to be amenable to group administration, (2) large and/or expensive equipment requirements had to be avoided, (3) prerequisite skills had to be minimal to avoid extensive pre-training or the need to use highly selected subject populations and (4) the topics had to be "new" to the Ss.

Finally, it was concluded that the selected courses should lend themselves to alternate methods of instruction. This criterion was more restrictive than it appeared at first to be since the statistical testing of second order interaction effects required that the instructional methods selected for investigation be the same for all courses. Although it seemed possible, for example, to teach tracking tasks by means of several distinct approaches, these same training methods could not, it appeared, be used for instruction on verbal, numerical, mechanical, clerical, or other types of tasks.

Identification of courses which met all of the criteria specified above was quite difficult. Many topics were identified which met all criteria except relevancy to Navy training programs. Topics most relevant to Navy training did not meet one or more of the other requirements. To reach a decision, discussions were held with NTDC personnel in Orlando, Florida. During the course of these discussions, agreement was reached to use linear programming, an operations research technique, as the subject matter for one experimental course. A suggestion was made at that time that photo-interpretation should be investigated as a possible second topic for experimental training.

Subsequent to the Orlando discussions, project personnel consulted with several subject matter and training experts to delineate more specifically the content and nature of the experimental training courses.

Based on these discussions, it was concluded that one linear programming topic, the Transportation Technique, and one photo-interpretation topic, Aircraft Recognition, would satisfy all criteria relevant to the selection of material for experimental training.

The first of these topics, the Transportation Technique, was entirely numerical in content. Arithmetic skills (addition, subtraction, and multiplication) were its only prerequisites, yet it was not likely that any of the subjects used in the study would have been exposed to it previously.

The second selected topic, Aircraft Recognition, required only visual discrimination skills. The specific experimental training task was to identify aircraft from aerial photographs. Learning of this topic imposed no requirements for acquisition of prerequisite skills or knowledges. The topic also had the advantage that few, if any, of the experimental subjects would have had prior experience in the area.

The contents of the two topics were distinctly different. They required factorially distinct learner abilities yet each topic was internally homogeneous and both were at least partially relevant to Navy career fields.

C. Selection of Training Methods

As was mentioned above, the selection of training methods for this study occurred simultaneously with the decisions which were made regarding training topics and the identification of learning styles. The selection of training topics could not be made independently of instructional method considerations, and both of these factors interacted with decisions regarding the identification of learner characteristics.

It was originally assumed that the two training approaches employed in the previous study of this series (Tallmadge & Shearer, 1967) would be used again. The investigation of training topics, however, revealed that neither the "rote memorization of procedures" nor the "understanding of principles" methods could be applied to all of the most promising topics under consideration. A decision was finally made to adopt inductive and deductive instructional methods for the study.

The decision to adopt these two training methods for the present research was based on many considerations aside from their "fit" with the other experimental variables. The most important of these was the wealth of available literature relevant to the overall effectiveness of these approaches (Anderson, 1967; Krumboltz & Yabroff, 1965).* A second consideration was that the latter report also indicated the existence of a possible interaction between these instructional methods and intelligence.

An issue closely related to the existence of studies investigating inductive and deductive methods was the fact their findings have frequently been contradictory. It appeared not unlikely that these contradictory results may have been due to the topics which were taught. It was felt that the present study, by employing two distinct training topics, could contribute significantly to the resolution of this issue.

D. Experimental Design

The basic experimental design involved two subject matter areas (topics) and two instructional methods. There were thus four treatment groups: (1) Transportation Technique, Inductive (TTI), (2) Transportation Technique, Deductive (TTD), (3) Aircraft Recognition, Inductive (ARI), and (4) Aircraft Recognition, Deductive (ARD). In addition, it was planned that Ss would be divided into two groups (those scoring above the median and those scoring below the median on selected individual difference measures or combinations of measures) thus enabling separate data analyses using a 2 x 2 x 2 factorial analysis of variance model for each selected measure or combination.

The design of the study required that Ss be assigned randomly to the treatment groups since assignments based on any single individual difference measure or any one combination of such measures would systematically bias analyses involving other measures.

* Inductive and deductive instructional methods are frequently termed "example-rule" and "rule-example" approaches respectively in the literature.

E. Development of Training Courses

Courses to be used in this study were developed by project personnel with consulting assistance from subject matter experts. Since the courses covered fairly basic topics in their fields, a minimum of consulting aid was necessary. The courses were designed for normal classroom presentation to reflect standard Navy training practices.

Although training time requirements differed slightly as a function of the subject matter being taught, the inductive and deductive versions of each course were matched with respect to duration in order to minimize criterion contamination problems. For the same reason, the instructional objectives of the two versions of each course were identical.

Behavioral objectives for each of the two subject matter areas were specified in a manner similar to that described by Mager (1962) before course development was initiated. Subsequent course development activities were specifically tailored to reflect these predetermined objectives in order to ensure that the inductive and deductive versions of the experimental courses differed only in terms of instructional method.

1. Transportation Technique

Two experimental Transportation Technique courses were developed; one inductive, and the other deductive. The courses were designed to teach Ss how to set up and solve simple transportation or shipping problems using the appropriate operations research techniques. Both courses covered the following topics: (1) Introduction to Operations Research and the Transportation Technique, (2) Finding Feasible Solutions, (3) Strategy for Improving on the First Feasible Solution, and (4) Least Cost Solutions. Both courses included lecture presentation, chalkboard demonstrations, practice problems (handouts), and review.

a. The Deductive Course

The Deductive Experimental Course was designed to be taught in such a way that Ss were essentially told and/or shown how to apply certain rules and procedures necessary to finding solutions to shipping problems. Ss were not informed why the various steps were necessary nor were they told why the procedures "worked". They were merely informed what the rules were and that the procedures would work if used correctly.

Solving a typical shipping problem involved performing a number of discrete operations in sequence. For training purposes, the different operations were taught separately and added one at a time to those already taught until the entire set of procedures had been covered.

b. The Inductive Course

In the inductive version of the Transportation Technique course, Ss were given a certain amount of basic information and then were guided to discover for themselves, through questions and presentation of partial information by the instructor, how to solve shipping problems and why the problem-solving procedures worked.

An interesting methodological question arose with respect to the meaning of "inductive" as applied to the Transportation Technique course. There appeared to be two distinct ways in which learners could be led to induce the procedural steps necessary to solve Transportation Technique problems. The first, and now almost classical, inductive instructional approach is to present a series of examples to students until they are able to identify the common element or governing "rule". This approach can be employed to teach any subject which involves rules -- regardless of whether these rules are arbitrary conventions (as are the "rules" of grammar and etiquette, for example) or whether they are logical and consistent (as the "rules" of mathematics and science are).

For topics which have logical and consistent rules, there is a second inductive approach. It involves leading the students not only to discover the common elements or rules but also to grasp the inherent logic, meaningfulness, or truth of the rules they discover. To illustrate this distinction it would be possible to teach the topic of "levers" in such a way that the students would induce the mathematical formulas required to solve lever problems without ever acquiring an understanding of why these formulas "make sense". The induced formulas would be learned by rote and, if forgotten, could not be recreated by the student. It would also be possible, however, to lead students to discover why levers work as they do and to gain an understanding of the principle involved. In this latter case, if a student forgot a formula, he should be able to recreate it based on his understanding of the principle.

The content of the Transportation Technique course was such that either of these two teaching approaches could have been adopted. Project personnel chose the latter approach -- primarily because evidence from the Phase II study had shown it to be an effective training method.

There are two important implications which resulted from this choice. First, although one version of the course was taught inductively, the "inductive method" was somewhat different from the typical example-rule approach. This fact must be kept in mind when comparing the results of the present study with others reported in the literature which employed the more typical inductive approach.

The second implication concerns the problem solving technique covered by the Transportation Technique courses. The standard problem solving procedures as presented by most textbooks on the topic (and as taught in the deductive version of the course) were not amenable to the type of inductive instructional approach which was selected. These procedures, although relatively straightforward, simply do not "make sense" intuitively (except, perhaps, to a highly sophisticated mathematician). Other problem solving procedures are "discovered" quite naturally by students when an inductive training approach is employed. These "other" procedures,* however, do not significantly affect the overall problem solving strategy or the final solution. Use of this approach was not, therefore, considered to be a problem since the specific behavioral objectives were identified for both versions of the Transportation Technique course.

* The main difference between the standard textbook approach and the intuitive approach is that the former selects ways to improve upon the initial problem solution by a process of evaluating empty cells in the Source-Destination matrix while the latter evaluates the cost savings associated with specific changes made to the initial shipping plan.

2. Aircraft Recognition

Two experimental courses were developed which involved a visual discrimination task, i.e., that of identifying aircraft from aerial photographs. One of the courses was designed to be deductive and the other one inductive as was the case with respect to the two experimental Transportation Technique courses.

Initially, aerial photographs of a large number and variety of aircraft were obtained. Micro-photographs were then taken and aircraft were selected for inclusion in the two experimental courses which provided for variety in terms of size, configuration, etc. Another criterion for inclusion was the availability of several different photographs of each aircraft to ensure variety from the standpoint of ease of identification.

Two sets of black and white slides were next prepared. The first set consisted of slides of portions of aerial photographs designed to show how aircraft appear in aerial photographs. This set of slides also illustrated some of the common problems which photo-interpreters encounter which may render aircraft identification difficult. Included in this set of slides were examples which showed poor contrast between aircraft and background, distortion, and partial obscuring of aircraft by such things as clouds, hangar roofs, and camouflage. The second set of slides included top view silhouettes of all aircraft to be taught in the experimental courses plus some of additional aircraft which were to be shown only as part of the deductive course.

a. The Deductive Course

One of the Aircraft Recognition courses was designed to be taught deductively. Included in this course was instruction on a system designed to help Ss identify aircraft. The system made use of an arbitrary set of specific recognition features related to wings, horizontal tail surfaces, fuselages, and engines. One additional feature consisted of what was termed unique characteristics.

Sixteen aircraft were taught using the system of recognition features. A slide showing a top view silhouette of each aircraft was presented along with some general interest information and a detailed description of the aircraft in terms of specific recognition features. After four aircraft had been presented individually, slides of the four aircraft were used for review. This in turn was followed by a series of practice exercises which Ss completed and which were subsequently discussed. The same process was then repeated for the next four aircraft with inclusion of an additional practice exercise which contained all the aircraft covered up to that point. This cycle continued until all 16 aircraft had been taught.

b. The Inductive Course

The second Aircraft Recognition course was designed to be taught in an inductive manner. The same 16 aircraft were taught and the presentation included the identical general interest information about these aircraft. However, Ss in the inductive course were not taught any system of recognition features nor were the aircraft described in terms of these recognition features, as was the case in the deductive course. Again, aircraft were taught in groups of four, and instruction on each group was followed by a practice exercise covering all aircraft taught up to that point.

In order to compensate for the course time lost due to not presenting a system for identifying aircraft using specific recognition features, it was necessary to increase the number of times each aircraft slide was presented and the length of exposure during the training and review sessions. Ss were shown slides of aircraft and were essentially left to evolve their own system for discriminating between aircraft. When questions arose concerning identifying aircraft presented in practice exercises, project staff members who acted as monitors did not mention wing shapes, number of engines, etc. They did pose questions designed to encourage Ss to devise their own system for identifying aircraft.

F. Development of Criterion Measures

Criterion tests were developed for the two subject matter areas directly from the statements of behavioral objectives and prior to course development. The same criterion test was used for both the inductive and deductive versions of each course.

1. Transportation Technique

A 25-item examination was developed which included all types of transportation problems which Ss had been taught to solve. Examination items were tried out using naive non-professional A.I.R. personnel to obtain information regarding difficulty levels and the amounts of time required to complete items. The examination was revised on the basis of these tryouts and items were arranged approximately in order of increasing difficulty.

Because the solving of Transportation Technique problems is an iterative process involving (sometimes many) successive approximations to the final, least-cost solution, a test scoring system was developed to provide partial credit for partial problem solutions and a bonus for obtaining the least-cost solution. This scoring system provided a possible range of scores from 0 to 117.

2. Aircraft Recognition

A 56-item criterion examination was constructed for the Aircraft Recognition courses. Each item consisted of an aerial photograph which contained one or more aircraft. The specific aircraft that Ss were to identify was circled in black. Four of the aircraft covered in the training were not included in the examination and five aircraft were included in the examination which were not covered in the course. This procedure was adopted because there was some interest in assessing the effectiveness of different training approaches for the recognition of "new" aircraft. Ss were instructed to write the designation of the aircraft in the space provided they knew it and to write an "X" in the blank if they were sure they had not been taught that particular aircraft.

The test was scored simply by counting the number of correct responses.

G. Study Implementation

1. Collection of Individual Difference Measures

Subjects for the study were 231 Navy enlisted men awaiting assignment to Basic Electricity and Electronics School in San Diego. All the psychological tests described earlier in this report were administered to groups of approximately 30 Ss during the first day of the two-day experimental period. All test administration was conducted by members of the project staff to assure consistency of procedures from testing session to testing session. Two project staff members were present at all testing sessions. Each testing session lasted approximately seven hours including "breaks". Scores on the four Basic Battery tests were provided by Naval Training School personnel for each S.

2. Course Administration

All experimental courses were presented at Naval Training School facilities with project personnel serving as instructors. Several instructors participated in the study to avoid problems associated with a possible "instructor effect". Each course was taught to approximately 30 Ss during the second day of the two-day testing/training period. Altogether there were eight experimental treatment groups, two for each version of each course. Two instructors were present during each administration. The experimental classroom sessions consumed approximately one full day (the Transportation Technique courses required slightly longer than the Aircraft Recognition courses).

3. Collection of Criterion Data

Criterion tests were administered to all Ss by project staff members immediately following completion of instruction. Again, two instructors were present to facilitate testing and monitoring.

The Transportation Technique criterion examination required one hour while the Aircraft Recognition examination required approximately one-half hour.

III. RESULTS

A. Preliminary Analysis

It was intended that analysis of variance techniques would be employed as the primary data analysis tools. Because of the large number of individual difference measures which were collected, however, it was considered neither feasible nor appropriate to conduct a separate analysis for each measure and for all possible combinations of measures. For this reason, an initial correlational analysis was performed.

For each of the four treatment groups, product moment correlation coefficients were calculated between scores on the 28 individual difference measures and the criterion test scores. These correlations are presented in Table 1.

Tests of the significance of the differences between correlations were made for each individual difference measure for the following pairs of correlations: (1) Transportation Technique Inductive (TTI) and Transportation Technique Deductive (TTD), (2) Aircraft Recognition Inductive (ARI) and Aircraft Recognition Deductive (ARD), (3) TTI and ARI, and (4) TTD and ARD.

Among the cognitive measures, there were only three statistically significant correlational differences. In all cases these differences were between the TTI and the ARI correlations and the three tests which produced the differences were basically numerical in nature [Navy Arithmetic Test ($p<.01$), Short Employment Test - Numerical ($p<.05$) and Locations Test ($p<.05$)]. In the case of these three tests, differences between the TTD and ARD correlations were in the same direction but too small to be statistically significant. Because of the numerical nature of the Transportation Technique courses and the absence of numerical involvement in the Aircraft Recognition courses, the obtained correlational differences were entirely predictable.

A very different picture was obtained with the non-cognitive individual difference measures (Kuder and Gordon scales). A substantial number of significantly different pairs of correlations were found among these measures (See Table 2). Typically, the correlations associated

TABLE 1

Correlations between Individual Difference Measures and Criterion Test Scores within Each Treatment Group

	Transportation Technique		Aircraft Recognition	
	Inductive	Deductive	Inductive	Deductive
Navy General Classification Test	.212	.181	.294*	.315*
Navy Arithmetic Test	.605**	.348**	.129	.122
Navy Mechanical Test	.341**	.320*	.123	.179
Navy Clerical Test	.273*	.318*	-.092	.044
Short Employment Test - Numerical	.344**	.311*	-.127	-.040
Short Employment Test - Verbal	.120	.012	.230	.368**
Letter Sets Test	.313*	.404**	.173	.087
Locations Test	.375**	.414**	-.072	.103
Figure Classification Test	.060	.299*	-.064	.039
Picture-Number Test	.143	.152	.225	.378**
First and Last Names Test	.092	.161	.359**	.360**
Finding A's Test	.140	.231	-.151	-.081
Identical Pictures Test	.115	.250	-.052	.185
Logical Reasoning Test	.267*	.283*	.216	.192
Inference Test	.188	.234	.133	-.001
Kuder - Mechanical	.193	-.132	-.079	.153
Kuder - Computational	.304*	-.022	-.217	.180
Kuder - Scientific	.438**	-.140	-.259*	.196
Kuder - Persuasive	-.215	.014	.066	-.220
Kuder - Artistic	-.228	.009	.167	-.026
Kuder - Literary	-.127	.088	.033	.004
Kuder - Musical	-.205	.215	.213	.037
Kuder - Social Service	-.033	-.155	.162	-.310*
Kuder - Clerical	-.082	.018	-.176	.195
Gordon - Ascendancy	-.192	.134	.255	-.166
Gordon - Responsibility	.241	.307*	.157	-.059
Gordon - Emotional Stability	.232	.233	.164	.115
Gordon - Sociability	-.221	-.046	.186	-.292*

* $p<.05$

** $p<.01$

TABLE 2

Pairs of Correlations (Individual Difference Measures with Criterion Test Scores) Which Were Significantly Different

Kuder - Mechanical	----	----	----
Kuder - Computational	TTI - ARI**	----	ARI - ARD*
Kuder - Scientific	TTI - ARI**	TTI - TTD**	ARI - ARD*
Kuder - Persuasive	----	----	----
Kuder - Artistic	TTI - ARI*	----	----
Kuder - Literary	----	----	----
Kuder - Musical	TTI - ARI*	TTI - TTD*	----
Kuder - Social Service	----	----	ARI - ARD*
Kuder - Clerical	----	----	----
Gordon - Ascendancy	TTI - ARI*	----	ARI - ARD*
Gordon - Responsibility	----	----	----
Gordon - Emotional Stability	----	----	----
Gordon - Sociability	TTI - ARI*	----	ARI - ARD*

* $p<.05$

** $p<.01$

with each of the non-cognitive individual difference measures showed the pattern depicted in Figure 1 (or its reverse).

	Transportation Technique	Aircraft Recognition
Inductive	Positive Correlation	Negative Correlation
Deductive	Negative Correlation	Positive Correlation

Fig. 1. Typical pattern of correlations between non-cognitive individual difference measures and criterion test scores.

B. Analyses of Variance

The pattern of correlations shown in Figure 1 pointed strongly to the existence of a significant interaction among instructional methods, subject matters, and learner characteristics. To test the hypothesis that such an interaction existed, a decision was made to categorize the entire trainee population into one of two groups depending on whether Ss scored above or below the median on the Kuder Scientific Interest scale. (This Kuder scale was chosen because it showed the largest correlational differences among treatment groups.) An unweighted means analysis of variance technique (Winer, 1962) was then used to analyze criterion test score data. The results of this analysis are presented in Table 3.*

TABLE 3

Unweighted Means Analysis of Variance

Source	df	MS	F	p
Inst. Methods (A)	1	439.35	4.85	$<.05$
Subject Matters (B)	1	67.33		
Sci. Int. Levels (C)	1	1.13		
A x B	1	1116.94	12.34	$<.001$
A x C	1	111.83		
B x C	1	225.92		
A x B x C	1	760.03	8.39	$<.005$
Error	222	90.55		
Total	229			

* Raw scores on the two criterion tests were standardized ($\bar{X} = 50$, $\sigma = 10$) prior to data analysis. This standardization served the purpose of removing all differences between the two subject matter areas. The original differences in raw scores could only be attributed to the lengths and difficulty levels of the criterion tests -- not to any inherent differences between the subject matters -- and could be seriously misinterpreted if not removed. Their removal, however, did not affect interactions between subject matter and the other two independent variables in any way.

As can be seen from Table 3, three significant F ratios were obtained. The inductive method proved significantly more effective on an overall basis than the deductive method. The methods by subject matters interaction effect was also significant, however, and further analysis showed that the inductive method was significantly superior to the deductive method for the Transportation Technique course ($p<.01$) but that the deductive method was superior for the Aircraft Recognition course (although this difference was not statistically significant). Mean criterion test scores for the four treatment conditions are presented in Table 4.

TABLE 4

Mean Criterion Test Scores for Each Treatment Condition

	Transportation Technique	Aircraft Recognition
Inductive	53.57	49.19
Deductive	46.16	50.81

Interpretation of the data was further complicated by the significant instructional methods by subject matters by interest levels interaction. To assist in interpreting this interaction, the mean criterion test scores were computed for each "cell" in the experimental design. These data are presented in Table 5. For the Transportation Technique courses, these data show (as did the data in Table 4) that the inductive instructional method was superior to the deductive method. The between method differences, however, are large and statistically significant ($p<.01$) only for

TABLE 5

Mean Criterion Test Scores for Each Cell in the Experimental Design

	Transportation Technique		Aircraft Recognition	
	Inductive	Deductive	Inductive	Deductive
High Scientific Interest	57.40	45.45	47.00	51.56
Low Scientific Interest	49.73	46.93	50.68	49.70

the High Scientific Interest group. They are small and not statistically significant ($p>.20$) for the Low Scientific Interest group.

Data for the Aircraft Recognition courses show that the inductive method was more effective for the Low Scientific Interest group but that the deductive method was more effective for the High Scientific Interest group although neither of these differences was statistically significant.

These findings relative to the Kuder Scientific Interest scale was strongly indicative of the existence of individual differences which could be labeled learning styles. Since other individual difference measures showed the same patterns of relationship to criterion test scores under the various treatment conditions, it appeared that a combination of such measures would magnify the differences found with the single Kuder scale.

In order to develop an appropriate composite test battery the following procedures were employed. Four separate Wherry-Doolittle Test Selection procedures (Wherry, 1940) were initiated simultaneously -- one for each treatment group. Instead of following the prescribed procedures of "adding" tests to the battery according to the size of their residual correlations separately for each analysis, tests were added in order of their average residual correlation across the four treatment groups. In this way a single combination of tests was selected which maximized prediction for the four groups (although, for any single treatment group, a better combination of tests could have been found).

A total of three individual difference measures were selected in this manner (the addition of a fourth test produced shrinkage of the multiple correlation). These measures were the Kuder Scientific Interest scale, the Gordon Ascendancy scale, and the Kuder Musical Interest scale. For the inductive version of the Transportation Technique course and the deductive version of the Aircraft Recognition course, the Scientific Interest scale was positively weighted and the other two scales were negatively weighted. For the deductive version of the Transportation Technique course and the inductive version of the Aircraft Recognition course, the "signs" of these weights were reversed.

Changing the signs of the weights for the latter two treatment groups made these signs the same for all four treatment groups and produced the same pattern of correlations as was shown in Figure 1. These weights were then averaged to yield a single regression equation which could be used to predict criterion test scores for all treatment groups. Positive predictions resulted from use of this equation for the TTI and ARD groups, and negative predictions resulted for the TTD and ARI groups).

The regression weights determined in this manner were +.5 for the Kuder Scientific Interest scale, -.4 for the Gordon Ascendancy scale, and -.3 for the Kuder Musical Interest scale. Because of the manner in which they were determined, these regression weights did not provide optimum prediction for any single treatment group. There is evidence, however, from other studies (Burt, 1949; Lawshe & Schucker, 1959; Wesman & Bennett, 1959) that even quite large deviations from the optimum regression weights have very small effects on multiple correlations. It was concluded, therefore, that the predictions obtained from the "average" regression equation closely approximated the optimum predictions which could be obtained for each treatment group using the three selected tests.

Ss were again sorted into high and low groups (those scoring above the median and those scoring below the median) according to their predicted scores on this multiple test battery. Data were then analyzed using the same analysis of variance model employed earlier. Results of this analysis are presented in Table 6.

TABLE 6

Unweighted Means Analysis of Variance

Source	df	MS	F	p
Inst. Methods (A)	1	576.88	6.59	<.05
Subject Matters (B)	1	5.96		
Learner Characteristics (C)	1	46.56		
A x B	1	1189.54	13.59	<.001
A x C	1	1.14		
B x C	1	43.72		
A x B x C	1	1823.77	20.84	<.001
Error	220	87.51		
Total	227			

As in the case of the previous analysis, statistically significant F ratios were obtained for the instructional methods main effect, for the methods by subject matters interaction, and for the instructional methods by subject matters by learner characteristics interaction. Treatment group means for the first two of these effects were identical to those of the first analysis (see Tables 3 and 4) since only the learner characteristics dimension was changed in this second analysis. Cell means for the second order interaction effect did differ, however, from those presented in Table 5. These means are presented in Table 7. They are also depicted graphically in Figures 2 and 3.

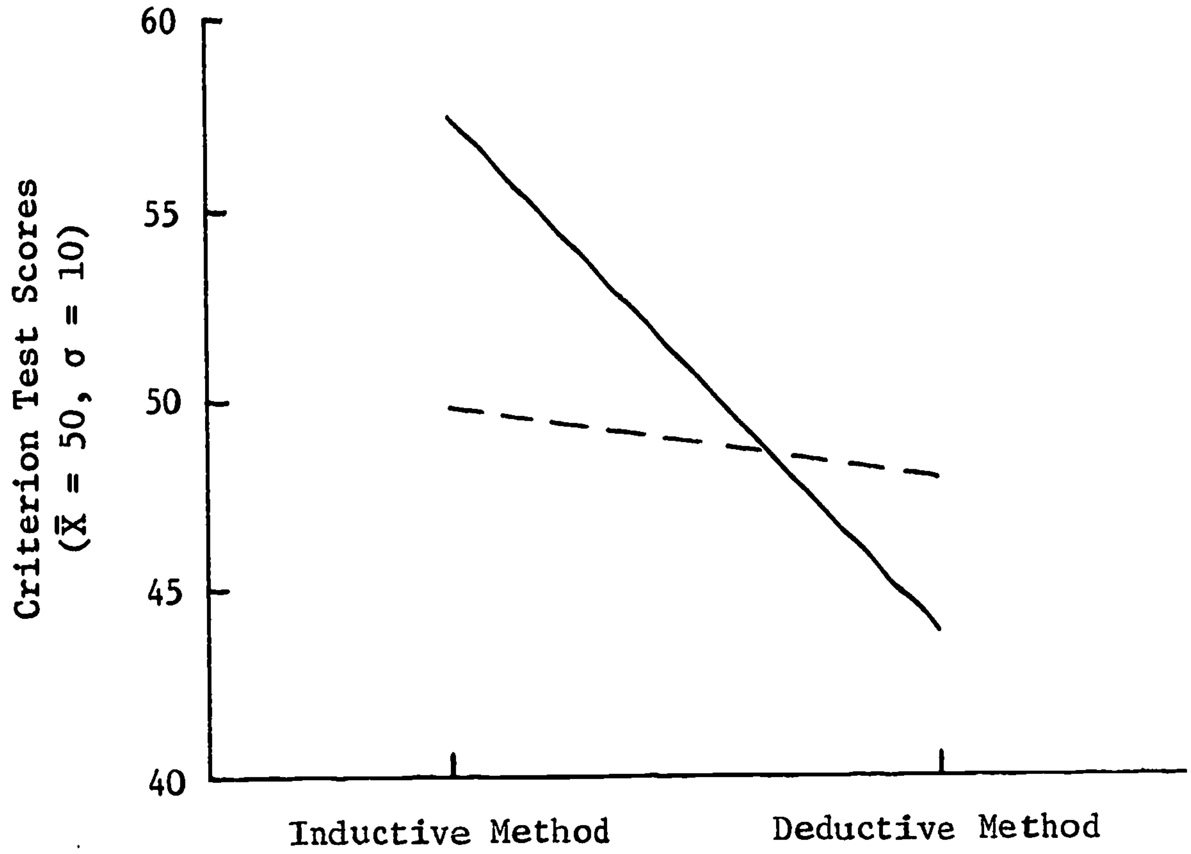

Fig. 2. Relationship between criterion performance and instructional methods for the Transportation Technique course. (The solid line represents Ss scoring above the group median on the composite measure and the broken line represents Ss scoring below the median.)

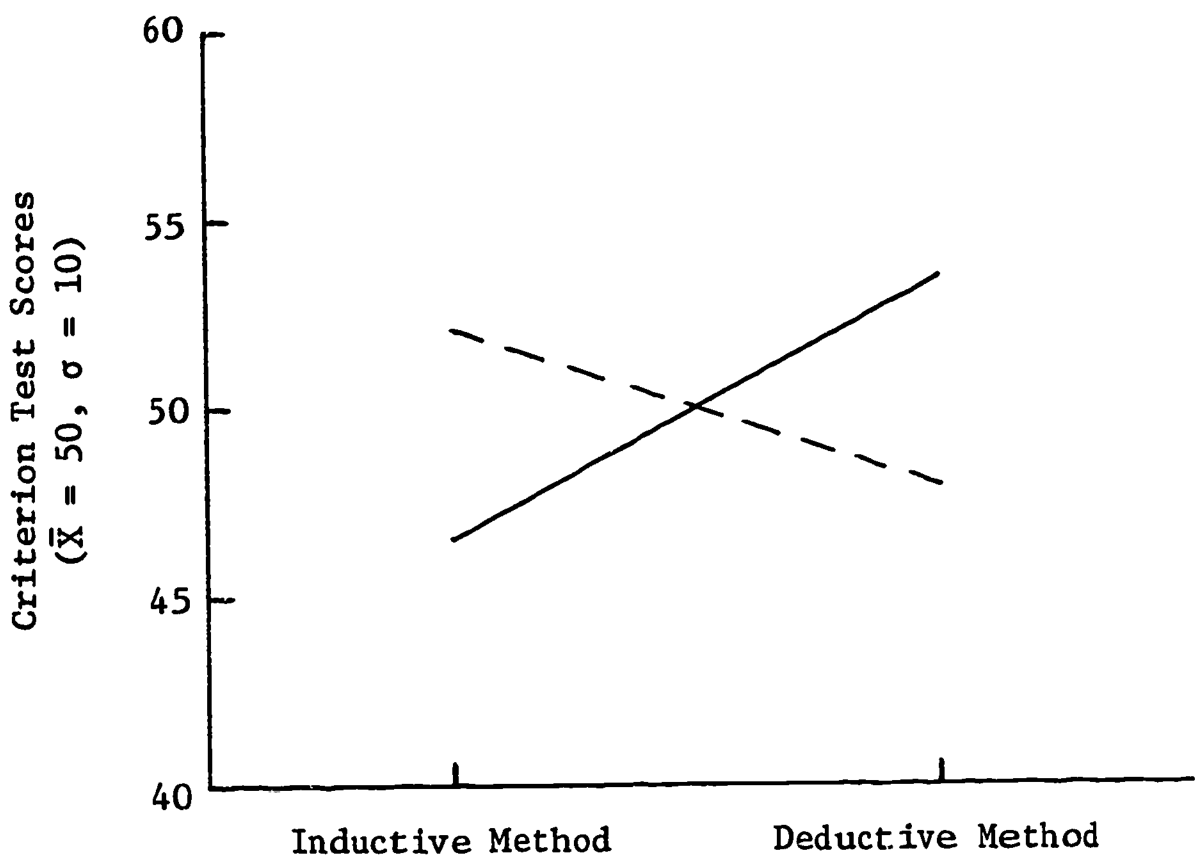

Fig. 3. Relationship between criterion performance and instructional methods for the Aircraft Recognition course. (The solid line represents Ss scoring above the group median on the composite measure and the broken line represents Ss scoring below the median.)

TABLE 7

Mean Criterion Test Scores for Each
Cell in the Experimental Design

	Transportation Technique		Aircraft Recognition	
	Inductive	Deductive	Inductive	Deductive
Group 1	57.48	43.92	46.68	53.61
Group 2	49.90	47.93	52.19	48.04

Simple effects tests performed on the data in Table 7 indicated that the inductive version of the Transportation Technique course was significantly superior to the deductive version ($p<.001$) and that the deductive version was significantly superior to the inductive version of the Aircraft Recognition course ($p<.001$) for Ss scoring above the median on the composite test battery. Neither of the differences between training methods was statistically significant for *Ss* scoring below the median on the composite measure.

C. Additional Analyses

A decision was made to compare *Ss*' actual achievement in the treatment groups to which they had been (randomly) assigned with their predicted performance under those treatment conditions for which their learning styles best suited them. The first step toward obtaining the required predicted scores was to develop a regression equation relating individual difference measures to criterion test scores for each treatment condition. This was accomplished using A.I.R.'s IBM 360/50 computer and the UCLA BMDO2R Stepwise Regression program. Since the objective of this analysis was to base the predictions on learning styles alone, only non-cognitive individual difference measures were included.

Liberal criteria for adding measures to the multiple regression equation were built into the program so that more predictors were selected than were ultimately used. Determination of how many tests to include in each regression equation was based on the standard error of estimate. As tests were added to the batteries, this standard error first decreased and then began to increase. Only those tests were included in the final regression equations which contributed to a decrease in the standard error of estimate.

Using this approach, the following regression equations were obtained:

(1) TTI = 36.4882 + .3392 (Gordon Responsibility) + .2507 (Gordon Emotional Stability) - .2589 (Gordon Sociability) + .2507 (Kuder Scientific) - .1674 (Kuder Artistic)

(Multiple r = .5612)

(2) TTD = 30.0178 + .6486 (Gordon Responsibility) + .1000 (Kuder Literary) + .1861 (Kuder Musical - .1002 (Kuder Social Service)

(Multiple r = .4810)

(3) ARI = 22.0682 + .4257 (Gordon Ascendancy) + .5523 (Gordon Responsibility) - .2779 (Gordon Emotional Stability) - .1083 (Kuder Scientific) + .2003 (Kuder Artistic) + .2447 (Kuder Musical) + .1179 (Kuder Social Service) - .0828 (Kuder Clerical)

(Multiple r = .5567)

(4) ARD = 65.5850 - .2803 (Gordon Sociability) - .1401 (Kuder Social Service)

(Multiple r = .3656)

These four regression equations were subsequently used to generate four predicted achievement scores for each S. Two "difference" scores were next calculated for each S -- (Inductive Transportation Technique) - (Deductive Transportation Technique) and (Inductive Aircraft Recognition) - (Deductive Aircraft Recognition). Ss were then sorted into high and low groups (above and below the median) on each of these "difference" measures.

For Ss in the high group on the Transportation Technique subject matter area, a mean predicted TTI score was calculated. A mean predicted TTD score was calculated for Ss in the low group. The same procedure was followed for the high and low groups in the Aircraft Recognition subject matter area. These predicted mean scores, which are presented in Table 8, represent the best possible estimates of average course achievement under conditions where Ss are assigned to instructional methods which match their learning styles.

TABLE 8

Mean Predicted Criterion Test Scores
-- Learning Styles Matched to Instructional Methods

	Transportation Technique	Aircraft Recognition
Inductive	57.27	53.26
Deductive	47.00	52.24

The means in Table 8 were compared with those in Table 4 by means of t tests. The mean scores for the "matched" assignment conditions (Table 8) were significantly higher than the corresponding mean scores for the "random" assignment conditions (Table 4) for the TTI treatment ($p<.02$) and for the ARI treatment ($p<.01$), but the differences were not statistically significant for either deductive course.

Mean scores were also predicted for "mismatched" conditions by following procedures opposite from those used to generate the data in Table 8. In other words, a predicted TTD (rather than TTI) score was calculated for Ss in the high group in the Transportation Technique subject matter area, etc. This procedure produced the best possible estimates of how well Ss would do if assigned to the instructional method which was least suited to their learning style. The results of these calculations are shown in Table 9.

TABLE 9

Mean Predicted Criterion Test Scores -- Learning Styles Mismatched to Instructional Methods

	Transportation Technique	Aircraft Recognition
Inductive	48.59	44.62
Deductive	45.21	48.06

Again, t tests were used to assess the differences between the predicted mean scores presented in Table 8 and those presented in Table 9. With the exception of the TTD treatment groups (which did not differ significantly), the differences between these means were all significantly different ($p<.01$). This finding indicated that matching instructional methods to learner characteristics produces a significant increase in learning effectiveness.

The largest difference, that between TTI with matched learning styles and TTI with mismatched learning styles, was 8.68 points. A difference of this magnitude corresponds to a percentile gain from the 44th percentile to the 77th percentile.

IV. DISCUSSION

The purpose of this study was to explore possible interactive relationships between learner characteristics and instructional method variables. Because other reported research has suggested that such relationships might be complicated by the content of the learning experience, subject matter was treated as an additional independent variable in this study.

The findings of the research strongly supported the existence of learning styles. Large and statistically significant interactions were found between learner characteristics and inductive and deductive instructional methods. It was also found that the direction of their interactive relationships reversed from a visual discrimination learning task to a logico-mathematical learning task.

The findings of the present study were not strictly comparable to other published studies because each such study has investigated a unique combination of learner characteristics, learning tasks, and instructional methods. There are some similarities, however, and some differences in experimental treatments and results for which tentative explanations can be offered in the light of the research reported here.

A. The Nature of Learning Styles

Evidence from this study, as well as from several others, indicated rather strongly that learning styles are non-cognitive in nature. Although 15 cognitive measures were investigated, none showed any interactive relationship with instructional methods -- and these measures were carefully selected to reflect differential aptitudes which were considered likely to produce interactions with the specific instructional methods studied.

Snow et al., (1965) reported some cognitive interactions with instructional media in the study described earlier but only when the extent of previous knowledge of the subject matter was simultaneously considered. These interactions also involved only the top and bottom 25 percent of the subject sample.

The findings of these authors are difficult to reconcile with those of the present study. It is not unreasonable to assume, however, that the novelty of the film presentation may have had differential motivational effects on those with prior knowledge and those without. In any case, as the authors themselves suggest, further research is needed to clarify these relationships. The reported findings are not sufficiently conclusive to negate the hypothesis that learning styles are at least primarily non-cognitive in nature.

Other studies have also reported interactions between cognitive learner characteristics and instructional variables. These studies, however, have generally been concerned with intelligence levels and with mechanical sorts of instructional procedures. Studies such as that of Molstad (1964) which found an interaction between step size in programmed instruction and IQ, although they were included in the discussion of relevant literature, are really felt to be peripheral to the issue of learning styles as considered here.

Small versus large steps in a programmed text is simply not the same kind of instructional variable as in an inductive versus a deductive teaching strategy. Step size appears to relate directly to the difficulty level of an instructional program, and one would therefore expect to find the type of relationship reported. The same is not true of the latter type of instructional "dimension". For this reason, studies concerned with variables such as step size are not considered relevant to the hypothesis that learning styles are essentially non-cognitive characteristics.

If one accepts the non-cognitive nature of learning styles, the next question to be answered concerns the nature of their non-cognitive components. Any analysis of these characteristics is likely, however, to depend heavily on the particular instructional conditions under which they are observed. Those learner characteristics, for example, which produced differential learning in response to inductive and deductive teaching methods might be completely unrelated to differences in learning observed under other instructional methods.

Again, the comparability among published research findings is limited -- a fact which precludes the formulation of broad generalizations. For this reason, the following discussion is primarily oriented toward the present study.

The best sources of information regarding the specific learner characteristics which comprised the observed learning styles were the four regression equations presented on page 40. Inspection of these equations revealed that the TTI and ARD equations had certain common elements as did the TTD and ARI equations. It was also apparent that some measures which appeared positively weighted in the first pair of equations appeared negatively weighted in the second pair, and vice-versa. [These findings were expected since a single regression equation was developed during the course of the data analysis which predicted performance in all treatment groups (see section B of the "Results" chapter)]. It was felt, however, that the regression equations had more in common than was readily apparent. This "feeling", coupled with the fact that the appearance of such variables as artistic, literary, and musical interests in the regression equations did not seem to make sense, led to further analysis.

There is extensive evidence in the literature (e.g., Becker, 1963; Bendig & Meyer, 1963; Overall, 1963; Schutz & Baker, 1962; Springob, 1963; Traxler & McCall, 1941; and Triggs, 1943) that the Kuder Mechanical, Computational, and Scientific scales are related to what has been called "Masculinity" and that the Literary, Musical, Artistic, Social Service, and Clerical scales are related to "Femininity". (The term "Masculinity", as used here, could perhaps be better described as an interest in technical subjects as opposed to social, cultural, and aesthetic subjects. These latter types of interests describe what psychologists have typically called "Femininity".) The measures included in the four regression equations do not precisely match these categorizations but they come close enough to suggest rather strongly that Ss with one learning style (that which produced improved learning under the TTI and ARD conditions) were characterized by technological interests and Ss with the other learning style (which produced improved learning under the TTD and ARI conditions) were characterized by social/aesthetic interests.

Other generalizations were also drawn from the regression equation data but, because less supportive evidence was available, these must be regarded as somewhat speculative. Again, evidence from the literature (e.g., Forer, 1955; Klugman, 1966; and Steinberg, 1952) has shown that scores on the Kuder Musical, Literary, and Social Service scales are positively related to anxiety level while scores on the Mechanical, Scientific, and Computational scales are negatively related to anxiety level. This evidence, coupled with the weights of the Gordon Emotional Stability scale (in the two regression equations in which it appeared), suggested that low anxiety might be an additional characteristic of Ss with the first learning style and that high anxiety might be an additional characteristic of Ss with the second learning style.

The third generalization was based on the weights of the Gordon Ascendancy and Sociability scales in the three regression equations which involved them. Since these scales were highly intercorrelated (r's = .762, .778, .729, and .653 for the four treatment groups) and both were characterized by preferences for outgoing, interpersonal kinds of activities (Buros, 1965), it was felt that both scales could be considered as measures of extroversion. Based on this evidence, then, Ss who performed best under the TTI and ARD treatment conditions could be described as interested in technology, possessing a low anxiety level, and introverted while Ss who performed best under the TTD and ARI conditions could be described as interested in social/aesthetic matters, possessing a high anxiety level, and extroverted. It should be pointed out that these descriptors cannot be considered to apply directly to the learning styles of the two groups of Ss. Rather, at this time at least, they must be considered as other individual characteristics which correlate with learning styles.

B. The Effects of Subject Matter Content

The subject matter variable in the present research produced some rather dramatic results. The pattern of relationships between learner characteristics and instructional methods for the Transportation Technique courses was exactly reversed for the Aircraft Recognition courses.

This relationship reversal might help to explain some of the contradictory findings reported by other researchers who investigated single (but different) subject matter areas. It would also help to explain some of the reported negative findings in cases where the subject matter research vehicle was a mixture of the two types of subject matters studied here. Tallmadge & Shearer (1967), in fact, attributed their negative findings to precisely this situation. They speculated that learner characteristics interacted with instructional methods in one way for a part of the experimental course they investigated but that the relationship reversed itself for other parts of the course so that the net effect was virtually zero.

It was felt that a thorough and detailed analysis of published research findings might help to clarify this issue, but it was not possible to perform this type of analysis within the scope of the present study. It was the general impression of project personnel, however, that the reported findings of studies which were reviewed were not inconsistent with the results reported here.

Further analysis of available literature might also shed some light on the main theoretical issue raised by the present research. This issue concerns the nature of the differences between the two subject matters studied. Which of the several differences between these subject matter areas was responsible for the reversal of relationships between instructional methods and learner characteristics?

The categories of learning discussed by Gagné (1965) do not appear to provide an adequate answer to this question. While one might argue that the inductive version of the Transportation Technique course represented a Type 7 learning situation (Principle Learning), and that the deductive version represented a Type 3 situation (Chaining), it would be necessary to describe the two versions of the Aircraft Recognition course in an opposite manner in order to explain the study findings. Since it was not possible to do so, other explanations had to be sought.

One of the major reasons that the two subject matter areas were originally selected was because they were distinctly different with respect to their governing "rules". The "rules" governing Transportation Technique problem solving procedures make sense intuitively when they are understood. They have the same kind of "truth" as equations in physics. One could no more change the rules governing the Transportation Technique than he could change the "law" of gravity.

The "rules" governing Aircraft Recognition, on the other hand, are arbitrary (at least in the absence of considerable aerodynamic sophistication). There are many individual characteristics which can be used to discriminate among aircraft -- or a "Gestalt" approach may be used. In any case, the discriminating features or "rules" must be learned by rote. They do not make sense nor do they possess any inherent logic or truth.

It was felt that this difference in meaningfulness was the critical difference between the two subject matter areas and that it, rather than the other differences, accounted for the study findings. Again, although the literature review produced no direct support for this hypothesis, it did not seem inconsistent with any published findings. Further research will be required to clarify this issue.

C. Instructional Method Variables

Aside from the rather thoroughly researched mechanical details of programmed instruction (step size, response mode, feedback conditions, etc.) the majority of instructional method studies have concentrated on differences between inductive and deductive techniques. Even in this rather restricted area, however, there have been significant differences among the practices followed. Some researchers have, for example, described inductive teaching as a guided discovery process while others have adopted a strict example-rule approach. It is also not always clear exactly how the experimental instruction was conducted.

Certainly the research which has been done has produced some fruitful results. There is an obvious lack, however, of a concerted and systematic program of research to seek answers to the many existing questions. Clearly, a taxonomy of instructional methods would do much to assure the comparability of study results and to enable generalizations to be made about the conditions under which different instructional approaches should be employed.

The present study is the only one known to the authors which has shown that the selection of a training method should be based not only on learner characteristics but also on the nature of the material to be learned. This finding should stimulate further research in the area. It is important, however, that future research carefully consider the need for a systematic approach to the treatment of both instructional method and subject matter variables.

D. Unanswered Questions

No single study ever provides conclusive answers to the questions it seeks to resolve. It is more frequently the case that studies raise more new questions than they answer. Certainly the present study has posed a number of new problems for which solutions must be sought through future research.

The issue which is perhaps the most significant, has already been alluded to. It concerns the identification and classification of subject matter variables which interact with learner characteristics and instructional methods. A tentative suggestion was made that inherent meaningfulness might be one such characteristic, but even this suggestion could only be offered as a potentially useful hypothesis for future research.

Subject matters could obviously be characterized in many other ways all of which might interact with learner characteristics and/or instructional methods. The fact that no attempts other than the present study have yet been made to identify this type of subject matter characteristic suggests that an important new area of research has been uncovered.

A second issue which requires further research is that of learning styles themselves. The question, "How many kinds of learning styles are there?" might well be asked. It is possible that as many learning styles may exist as there are instructional methods -- but it is not at all clear how many different instructional methods there are, or even how many dimensions exist along which instructional techniques can vary.

These are very difficult questions to deal with, expecially in view of the paucity of relevant research literature. A substantial amount of basic exploratory study will be required before it will be possible even to formulate plausible hypotheses.

A related issue concerns how to measure or predict learning styles. The present study employed existing psychological tests and found relationships between certain interest and personality variables and performance under different instructional conditions. The analyses performed on these measures suggested that predictive validities might be increased somewhat through use of different individual difference measures but provided no information as to whether learning styles are really a function of personality and interest characteristics. It may be that these characteristics are only peripherally related and it may be necessary to employ completely new measurement techniques to maximize predictive validity. There appears to be sufficient plausibility to this hypothesis to justify further investigation.

Investigation of these issues will, no doubt, raise new questions. It seems clear at this point, however, that relationships have been identified which are strong enough and large enough so that the potential payoff in terms of increased education and training effectiveness would more than justify the cost of additional research.

V. CONCLUSIONS

The results of this study strongly supported the existence of learning styles -- a type of learner characteristic shown to interact with instructional treatment conditions in such a way that large achievement gains resulted from matching learners to conditions.

The gains in training effectiveness which were shown to be achievable in this manner were of sufficient magnitude to suggest that multi-track instruction, based on learning styles, might be a cost-effective way of enhancing learning.

Of a total of 15 cognitive (aptitude) measures obtained on the experimental Ss, none showed tendencies to interact either with the subject matters or with the instructional methods which were investigated. The majority of the 13 non-cognitive (interest and personality) measures did show such interactive patterns, however. This finding led to the conclusion that learning styles are essentially non-cognitive in nature.

Two learning styles were discovered in the course of this research. Ss possessing the first learning style were characterized by technological interests, low anxiety, and introversion. These Ss performed best when the logico-mathematical subject matter (Transportation Technique) was taught inductively and when the visual discrimination course (Aircraft Recognition) was taught deductively. Ss possessing the second learning style were characterized by social/aesthetic interests, high anxiety, and extroversion. They performed best under instructional conditions which were the opposite of those found to be best for the other Ss.

VI. RECOMMENDATIONS

A. Recommendations for Present Training

Data from the present study showed that, under some conditions at least, a potential gain of some 33 percentile ranks in learning achievement can be realized by matching learners to instructional treatment conditions using scores obtained from the Kuder Preference Record and the Gordon Personal Profile. Total administration time required for these two tests is on the order of 30 to 45 minutes.

While gains of this magnitude might suggest the development of multi-track training programs based on learning style differences, this course of action cannot be recommended at this time. Further clarification is needed before it will be possible to analyze existing courses and determine which methods of teaching them will optimize achievement for different types of students.

The largest gain which was observed in the present study was that obtained by using an inductive, or guided discovery, method of teaching the Transportation Technique course to Ss with a matching learning style. This finding supported the results of the previous study in this series (Tallmadge & Shearer, 1967) and suggested that significant improvements in training effectiveness could be accrued by using both a guided discovery and a deductive or didactic instructional approach to subject matters of a logico-mathematical nature. Although both the present and the previous study showed the inductive approach to be superior on an overall basis for topics of this type, some trainees get lost if this is the only approach employed. These trainees need to be able to memorize step-by-step procedures. Using both teaching approaches for this type of subject matter therefore appears to be a sound first step toward the individualization of instruction.

B. Recommendations for Further Research

The "Discussion" section of this report has already pointed up some of the areas in which further research is required. Before additional studies are initiated, however, there appears to be an urgent need to assemble, analyze, and reinterpret the rapidly growing body of relevant research results. It is known that studies are currently in progress both here and abroad which may be expected to shed further light on learning style issues, and it is important that communication channels be established.

Even a cursory examination of the published literature reveals a marked tendency for recent studies to ignore, or at least to fail to profit from, the findings of earlier studies. One explanation for this tendency is the fact that many of the reported interactive relationships were accidental findings of studies designed to investigate simple relationships. For this reason, information is frequently difficult to locate.

Regardless of the reasons for deficiencies in this area, future research would almost certainly profit from a thorough and complete literature review.

Perhaps the most significant finding of the present study was the fact that relationships between learning styles and instructional methods depend on the subject matter being taught. The study did not, however, provide any answers to the question of what it is about different subject matters which produces this effect.

A thorough literature study can be expected to shed some light on this question. Almost certainly, however, further research will be required since subject matter has not previously been treated as an independent experimental variable. This question must be regarded as a very important issue for future research because research findings cannot be extended to practical applications until meaningful answers are obtained.

A third area in which additional research must be recommended is that of learning styles themselves. Here there are many questions: How many different kinds of learning styles are there? How can they best be measured? Are new test instruments required? etc. And the same questions can be asked about instructional methods themselves since a learning style can best be defined in terms of differential learning achievement under different instructional methods.

Evidence from the present study suggests that learning style is a non-cognitive personal characteristic but it is certainly not clear whether it should be regarded as a personality trait, interest pattern, motivational factor, or some combination of these variables.

Investigation of these issues will, no doubt, raise new questions. It seems clear at this point, however, that the existence of learning styles has been demonstrated and that the directions further research should pursue have been reasonably clearly indicated. Finally, there is strong evidence that further developments in this area will have practical implications for enhancing the efficiency and effectiveness of educational processes.

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STUDY OF TRAINING EQUIPMENT AND INDIVIDUAL DIFFERENCES: THE EFFECTS OF SUBJECT MATTER VARIABLES (SUPPLEMENTARY REPORT)

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ABSTRACT

The work reported here was a three-month effort undertaken for two closely related purposes. First, because a recently completed experimental study (Tallmadge, Shearer, & Greenberg, 1968) produced results which indicated that factors not previously considered had a profound effect on learner characteristic-instructional method relationships, a need was perceived for reexamining related studies to determine whether their apparently conflicting results could be explained in terms of these new findings. The second purpose was to use all available information in order to lay out some preliminary plans for future research. A conceptual model was developed, based on a literature analysis and discussions with other scientists concerned with this problem, which organizes type of learning, type of instruction, and type of subject matter into a three dimensional matrix which the authors argue should be used to guide future research. Based on the model and other considerations, preliminary plans were formulated for a study to demonstrate that significant effectiveness gains can be achieved through designing training to match specific learner characteristics.

FOREWORD

This report was prepared as part of a project entitled "Training Equipment and Individual Differences," the purpose of which is to investigate whether training efficiency is improved by employing training systems which differ in design and use as a function of differences in characteristics of the trainees.

In Technical Report NAVTRADEVCEN 67-C-0114-1, published in May 1968, the variable of subject matter content was introduced into the research design along with training methods and trainee characteristics. The results showed the importance of learning styles. As this variable was not originally considered, further analysis of the "learning styles" literature was indicated. This report, which is a supplement to Technical Report NAVTRADEVCEN 67-C-0114-1, assesses the current literature and proposes a conceptual model as a strategy for future research.

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On the practical side, visits were made to several Navy training activities. The value obtained from these visits was greatly enhanced through the efforts of many individuals who provided their time and expertise to assist project staff members. The authors are grateful to all of the following persons for their generous contributions: LtCdr. Leonard Leo and Mr. Gordon Crawford, Naval Schools Command, Treasure Island; Capt. T. J. Guinan, Lt. L. C. Krause, and Master Chief Winings, Naval Schools Command, Mare Island; Mr. Frederick W. H. Rothenberg, Mr. Len Hess, and Mr. Lowell E. Sell, Naval Training Device Center, West Coast Regional Office; Dr. Edwin G. Aiken and Mr. Edward Pickering, U. S. Navy Personnel Research Activity, San Diego; and Mr. Paul Asa-Dorian, Anti-Submarine Warfare School, San Diego.

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I. INTRODUCTION

A. Scope of the Study

The study reported here was of a brief (three month) duration. It was undertaken because a real need was perceived at the end of the previous study in this series to take a fresh look at the whole problem of interactive relationships between learner characteristics and instructional treatment conditions in an attempt to formulate a sound theoretical basis for further research and development activities.

Dramatic results were produced by the previous study (Tallmadge, Shearer, & Greenberg, 1968) which not only found that significant relationships existed between learner characteristics and training methods, but found as well that the nature of these relationships changed as a function of what was taught. It seemed important to attempt to reconcile these findings with the apparently conflicting research results reported by others and to see whether a common basis for explanation could be found.

It was also intended, as a part of this effort, to develop a preliminary plan of action for demonstrating the practical utility of designing multi-track training programs employing training devices which were specifically tailored to capitalize on differences among learning styles.

B. Summary of Activities

The primary activity during the three month reporting period consisted of intensive literature review and discussions held with other scientists working in the field. It became apparent during the course of this activity that the recently completed study (Tallmadge et al., 1968) was unique in its field by virtue of the inclusion of subject matter content as an independent variable. The discovery that subject matter is a variable which must be considered in research of this type did not, however, provide the hoped for key to explaining the many conflicting findings which have been reported. It seemed rather to further muddy the waters in such a way that studies which had once appeared straightforward could no longer be easily explained. This point is discussed in greater detail in the following major section of this report.

The literature review was useful in that many new studies dealing directly or indirectly with the individual differences/instructional methods problem were unearthed. The body of relevant data was thus enlarged and will, no doubt, provide valuable sources of information once adequate theoretical formulations have been achieved.

Useful also were the discussions held with others working in the field. Of special interest was an ongoing program of research at Stanford University under the direction of Dr. Lee J. Cronbach and sponsored by the U. S. Office of Education. Exchange of information with persons participating in this research program, particularly Dr. Richard E. Snow, provided many new insights. Further interchange of ideas is expected to be mutually beneficial and should significantly reduce the time required to achieve practical benefits from this research.

With respect to the planning aspects of this contract effort, visits were made to the U. S. Navy Schools Commands at Treasure Island and Mare Island and, in conjunction with several N.T.D.C. San Diego representatives, to the Fleet ASW School and the U. S. Navy Training Research Laboratory. The purpose of these visits was to survey training devices currently employed in ongoing training programs and to assess their amenability to alternative utilization modes for multi-track training. The conclusions reached as a result of these visits are summarized later in this report. The visits were beneficial, however, to the formulation of plans for further research and development.

C. Tentative Conclusions

This report must be regarded as highly speculative and preliminary in nature. No conclusions were reached with respect to the nature of psychological relationships existing among types of learning, types of learners, types of instruction, and types of subject matter. The only conclusion which could be drawn is that not enough specific research questions have been answered to provide an adequate basis for a sound theoretical formulation.

Largely because of an almost endless variation of subject matters taught and methods used to teach them, it is a nearly impossible job to compare reported studies. To cope with this problem a conceptual framework was developed which the authors feel confident can be useful in guiding future research. Because of ambiguities in experimental treatments, criterion measurements, and reporting procedures, however, most published studies could not be clearly categorized within the developed conceptual system. While attempts were made to find common elements in the studies which were reviewed, these attempts were only partially successful.

There can be no doubt that further research will be required before we can attain even a moderately complete understanding of relationships between learner characteristics and instructional treatment conditions. The discussions and "model" presented in the next section of this report, however, should serve to highlight some of the problems encountered by past research and should provide guidance to future efforts so that past mistakes will not be repeated.

II. ASSESSMENT OF THE CURRENT STATE OF THE ART

As mentioned earlier, an extensive literature review effort was undertaken during this three month contract period. The aim of this activity was not so much to identify studies relevant to the learning style issue -- this had already been done as an integral part of the previous study in this series (Tallmadge et al., 1968). While research not previously reviewed was uncovered, the primary purpose here was to find some pattern of consistency underlying the many apparently disparate findings which have been reported.

Many research reports were studied and many discussions were held among members of the project staff and with "experts" outside of A.I.R. It seemed that meaningful relationships did exist although the inferences which had to be drawn from available data were far from obvious, as will be seen in the subsequent development. There appeared to be many relevant factors but not all were ever represented in a single study. The authors, in fact, have not been able to assemble a logically "tight" justification for the theoretical formulations which follow. For this reason, they have chosen to present their theoretical speculations prior to their literature evaluation hoping that the latter will support the former but in full awareness of the many existing gaps.

A. Preliminary Model Formulation

An attempt was made, during this phase of the research program to find some theoretical rationale which could explain the many diverse findings of studies investigating the relative effectiveness of different instructional methods and interactions between learner characteristics and instructional treatment conditions. It was felt at the beginning of this effort that the previous study in this series (Tallmadge et al., 1968) provided some basic insights not heretofore available which might enable achievement of this goal.

Based on the above cited study, it was initially hypothesized that differences in the nature of the material which was taught could account for most, if not all, of the apparent discrepancies which exist among reported study findings. At the present time, however, this hypothesis can be considered only partially valid. While it does appear essential to consider subject matter variables in any analysis of learner-treatment relationships, many other factors must also be considered, and they must be considered at a level of specificity which is rarely available in the published literature.

It was not long before the authors of this report began to suspect that important differences existed among instructional treatments which had been given a single label. At this point in time it seems safe to conclude that some instructional methods labeled "inductive" are more like others which are labeled "deductive" than they are like other so-called "inductive" treatments. In cases where detailed descriptions of precisely how the instruction was conducted are not available, assumptions based on arbitrary labels were frequently found to be grossly misleading. And precise descriptions of criterion measurements are equally important to the correct interpretation of the literature in this field.

It is only recently that researchers and educators have concerned themselves directly with interactive relationships between learner characteristics and methods of instruction. Evidence available from these few research efforts is far from adequate to provide final answers to the many questions which have arisen. To some extent, additional data can be gathered from studies which found such interactions serendipitously while seeking main effect differences. This approach, however, has two severe limitations. First, studies which found such relationships are extremely difficult to locate since the relationships of interest here were rarely considered to be of much importance by the authors. Second, as has already been suggested, these studies rarely describe instructional treatments, subject matters taught, and criterion measures in sufficient detail to permit valid between-study comparisons.

In view of available evidence, there can be little doubt that what is taught, how it is taught, and to whom it is taught are all important considerations relative to the individualization of instruction. Since what is taught and what is learned are not always the same, it appears necessary to consider the nature of learning as well. This latter point is particularly valid in the context of modern instructional technology where learning objectives are stated in terms of observable criterion behaviors.

It is typical, for example, when designing instruction covering a topic like logarithms to specify kinds of logarithm problems which course graduates are expected to be able to solve. Then, if instruction is limited to these objectives, no theory would normally be taught. Some students, however, may figure out the underlying theory. They will learn not only how logarithms work, but why they work as well.

In Gagné's (1965) theoretical framework, students who learn only the procedures for solving problems experience a Type 3 or Verbal Chaining kind of learning while those who learn the rationale as well experience Type 7 or Principle learning. Both types of learning in this example can occur under the same instructional conditions. They cannot, as must be carefully emphasized, be discriminated by a criterion test which measures only problem solving ability. It must be made clear that the teaching does not necessarily determine the learning. This point is stressed here because the authors feel, although they can offer only indirect evidence at this time, that the type of learning actually experienced by the student has more impact on what Snow and Salomon (1968) have called "Aptitude Treatment Interactions" than has the type of learning which the experimenter intended to produce or the specific treatments he employed.

The extent to which what is taught and what is learned may differ appears to depend, at least in part, on the nature of the subject matter. If, for example, an American student is being taught to shift his fork from his left to his right hand before using it for eating purposes, there is no way in which this "lesson" can be made into one of Gagné's higher types of learning. The "rule" being learned is completely arbitrary -- so arbitrary, in fact, that people of other nationalities have an opposite rule. Because the rule is arbitrary, it can only be learned by rote. It cannot be made meaningful since it does not involve any of the type of rational principles which are necessary ingredients of the higher types of learning. On the other hand, a logarithm example has already been cited which, if taught as a "cookbook" procedure, may be learned as a meaningful principle or, if taught as a meaningful principle may be learned as a "cookbook" procedure.

An attempt has been made to depict the "interaction surface" of subject matters and types of learning in matrix form. This matrix is shown in Figure 1. Although it is undoubtedly an oversimplification of the true situation (Gagné's eight types of learning, for example, have been reduced to two -- "Understanding" and "Rote"), it appears to have some utility in providing a conceptual framework within which published studies can be more adequately described.

		SUBJECT MATTERS	
		Meaningful Rules	Arbitrary Rules
TYPES OF LEARNING	Understanding		
	"Rote"		

Fig. 1. Matrix showing relationship between subject matters and types of learning

The upper right hand cell in Figure 1 which corresponds to "understanding" learning of "arbitrary rules" subject matter has been crossed out for the reason discussed above. There simply is no way in which arbitrary conventions can be transformed into scientific or logical principles. The other three cells, however, do exist and have counterparts in the "real world" which are described in the following paragraphs.

The kind of learning situation which fits into the lower right hand corner of the Figure 1 matrix is perhaps the simplest, most straightforward, and easiest to describe. The rule of the road, "turn to the right to avoid potential head-on collisions", provides a good illustration of the kind of subject matter labeled "arbitrary rules". It is arbitrary because, to paraphrase Cronbach (1966, p. 79), it is no more correct "in the eyes of God" than a rule would be which said, "turn to the left". Because it is arbitrary, it can, of course, only be learned by rote.

The so called three minute rule used in various marine navigation applications provides a good example of a "meaningful rules" subject matter which can be learned either with understanding or by rote. The rule states that the hundreds of yards which a ship travels in three minutes is that ship's speed in knots. This rule is meaningful rather than arbitrary because it is logically derivable from physical laws. Whether or not the rule is correct in the eyes of God, it could not be changed to state that the hundreds of yards a ship travels in four minutes is that ship's speed in knots without becoming unquestionably wrong.

Clearly, the three minute rule could be learned by rote, and this type of learning would "fit" into the lower left hand cell of the Figure 1 matrix. It could also be learned with an understanding of its derivation. If learned in this manner, it would represent the type of learning falling into the upper left hand corner of the matrix. In this case, the student would be able to reconstruct the rule, if forgotten, by working backward from the basic premise that a knot is a nautical mile per hour. If the rule were learned by rote, this type of reconstruction would not be possible.

The two types of learning just described are clearly different and the distinction seems to be an important one with respect to aptitude-treatment interactions. One of the main difficulties, however, in interpreting the published literature is that it is often not possible to determine which type of learning has actually occurred from descriptions of the instructional treatments and the criterion measures. The three minute rule may be taught so as to include detailed explanations and derivations, yet the student may only memorize the formula. Conversely, the rule may be taught without explanation or derivation and the student may fill in these "gaps" through self-initiated analytical processes.

The Figure 1 matrix is an attempt at graphic portrayal of the interaction surface which exists between what is taught and what is learned. It is meant to point out that the subject matter taught does not necessarily determine the type of learning experienced by the student. This is particularly true in cases such as those cited where problems can be solved through the application of procedures which may have been either learned by rote or meaningfully understood.

It is, of course, true that a carefully constructed criterion test, designed for this purpose, could discriminate between the types of learning which had occurred. This circumstance, unfortunately, rarely occurs today where the emphasis in instructional material and criterion test design is placed, at the insistence of our instructional technologists, not on what a person knows, but on what he can do.* While this atmosphere prevails, a psychological dimension of the learning experience which the authors believe to be of critical importance in the study of aptitude-treatment interactions remains almost hopelessly obscured.

B. The Instructional Method Dimension

At the present time it seems neither feasible nor desirable to consider all the possible variations in instructional methods. Aside from several mechanical characteristics of programmed instruction (size of step, overt vs. covert response modes, etc.), the great preponderance of research has been concerned with two basic approaches which can be labeled expository-deductive and inductive-discovery. For this reason, the authors have chosen to limit their concern to these two broad categories.

While it is not always exactly clear which of these two labels should be applied to a given instructional treatment, more often there is little

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* Insistence on behavioral objectives is eminently sensible when one is concerned only with the outcomes of instruction. It does not necessarily follow, however, that the learning process -- the attainment of the behavioral objectives -- might not be facilitated by the inclusion of logically irrelevant material which transforms a meaningless series of steps into a meaningful operation.

doubt. Still, large treatment differences exist within each of the categories. When viewed in the context of the Figure 1 matrix, however, some of the more readily apparent differences begin to make sense. Studies, for example, which talk about "Example-Rule" treatments seem almost necessarily to be restricted to the rote learning cells while those which describe Socratic dialogues have a high probability of falling within the "meaningful rules subject matter-understanding learning" category.

Figure 2 is a modified version of Figure 1 to which a third dimension, instructional methods, has been added. The cells have been numbered 1 through 6 to facilitate further discussion.

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">SUBJECT MATTERS</td></tr>
<tr><td>Meaningful Rules</td><td>Arbitrary Rules</td></tr>
<tr><td rowspan="4">TYPES OF LEARNING</td><td rowspan="2">Understanding</td><td>1 Expository/ Deductive</td><td rowspan="2"></td></tr>
<tr><td>2 Inductive/ Discovery</td></tr>
<tr><td rowspan="2">"Rote"</td><td>3 Expository/ Deductive</td><td>5 Expository/ Deductive</td></tr>
<tr><td>4 Inductive/ Discovery</td><td>6 Inductive/ Discovery</td></tr>
</table>

Fig. 2. Matrix showing relationships among instructional methods, subject matters and types of learning

Before discussing specific studies, it seems appropriate to describe the kinds of instructional approaches which would represent good "fits" in each cell of the Figure 2 matrix.

Cell #1 Although, as was discussed previously, some students may experience an understanding type of learning when exposed to a strict "Rule-Example" form of instruction, it seems unlikely that this approach would be adopted if the intent were to produce understanding. A "Rule-Explanation-Example", or some variation of this sequence would appear to be far more appropriate. It must be pointed out again, however, that use of this approach will not guarantee that students will understand. Some may learn to apply the rule(s) successfully by rote even though an explanation was presented.

Cell #2 As was the case with Cell #1, the most commonly employed inductive-discovery approaches, "Example-Rule" or "Example Only" do not seem to be appropriate here. It is true that some students may discover meaningful concepts and principles but most are likely to discover only procedural rules. The Socratic dialogue approach as employed by Kersh (1962), for example, appears much more likely to produce an understanding type of learning. This approach, frequently called "Guided Discovery" (although this term has also been used to describe quite different instructional methods) involves the use of leading questions to guide the student, step-by-step, to discover or derive the rules he learns through a process of logical inference.

Cell #3 The type of instruction most frequently employed to produce deductive rote learning -- whether the subject matter is of the meaningful rules or the arbitrary rules variety -- has been labeled by educational researchers as the "Rule-Example" approach. The student is simply told how things are or what he is to do (never why) and then he practices for a fixed amount of time or until he attains a specified minimum level of proficiency. In the case of a meaningful rules subject matter, the student may independently discover the underlying concepts or principles in which case he "belongs" in Cell #2 although his classmates who did not make similar discoveries "belong" in Cell #3.

Cell #4 The "Example-Rule" or "Example Only" instructional method is the most frequently employed to produce inductive rote learning of either meaningful rules or arbitrary rules subject matters. The student is simply presented with examples of the application of some rule until he either discovers the rule or until it is given to him. If the student discovers the "why" as well as the "what", he belongs in Cell #2, not Cell #4.

Cell #5 The same instructional techniques are employed here as are used in Cell #3. The only difference is that the student cannot discover any underlying rationale since none exists. This cell, and Cell #6 represent the only instances where what is taught and what is learned must be the same.

Cell #6 The same instructional techniques are employed here as are used in Cell #4. The only difference is that the student cannot discover any underlying rationale since none exists.

There are, of course, many variations on the instructional methods described, as well as "mixed" approaches. Primarily, these "hybrids" have been developed by researchers concerned with the overall effectiveness of instructional methods rather than with aptitude-treatment interactions. Such studies only seem to confuse the basic issues, however, as it is frequently not possible even to guess at the type of learning produced.

It appears reasonable at this time that if well controlled studies existed which provided comparisons between all possible pairs of the Figure 2 matrix cells we would have a far more complete picture of the relative effectiveness of inductive and deductive instructional methods than was recently reported in a seemingly overly simplistic manner by Anderson (1967). Such studies do not exist, however, or at least they cannot be recognized. In fact, despite the voluminous literature in this field only a few of the many possible comparisons have been made. Even where good studies have been reported it is frequently not possible to say with any degree of certainty exactly which "cells" had been compared.

Adding the complication of aptitude-treatment interactions, of course, significantly reduces the amount of relevant information which is available and few, if any, conclusions can be drawn with confidence.

C. Critical Evaluation of the State of the Art as Reflected by the Research Literature

Most of the published studies which deal with instructional methods have had as their primary concern the relative effectiveness of one instructional method as opposed to one or more other methods. Although it has been said that most of these instructional methods can be grossly categorized as either inductive-discovery or expository-deductive, the authors of this report encountered the following "descriptive" labels reported in the literature: expository, structured search, heuristic, heuristic-successive, heuristic-simultaneous, show and tell, discovery, Socratic, lecture, rote, guided discovery, explanation, drill, example-rule, rule-example, unverbalized awareness, why, inductive, deductive, conscious generalization, tell-and-do, reasoning, didactic, didactic-successive, didactic-simultaneous, understanding, inductive-discovery, directed discovery, and expository-deductive. This list speaks for itself, and it is not an easy matter to determine whether the labeled method properly belongs in the inductive-discovery or the expository-deductive category. While authors such as Sieber and Kameya (1968) evidenced desirable thoroughness in providing detailed descriptions of the instructional methods they employed, other authors, for example Morgenstein and Pintel (1968), included no description whatsoever.

Despite this type of difficulty, attempts have been made to draw generalizations from the published literature. Anderson (1967) reached the conclusion that the evidence overwhelmingly supported the superiority of deductive over inductive instructional methods. Krumboltz and Yabroff (1965, p. 223) on the other hand, reached the following conclusion. "Empirical evidence has not supported any one consistent set of hypotheses with regard to the relative efficacy of the inductive and deductive teaching methods. Some studies reported the inductive method superior (Haslerud and Meyers, 1958; Hendrix, 1947; Kersh, 1958; Ray, 1961); others reported findings in favor of the deductive method (Craig, 1953, 1956; Fowler, 1931). Still other studies found the two methods equally effective (Forgus and Schwartz, 1957; Nichols, 1957, Sobel, 1956)." In one study where subject matter was treated as an independent variable (Tallmadge et al., 1968), the inductive method was found to be superior for one learning task while the deductive method was superior for the other. It clearly appears then, and this conclusion is also supported by Krumboltz and Yabroff, that neither instructional method is clearly superior to the other on an overall basis. Other factors including learner characteristics, subject matters, and types of learning must also be considered.

It was this type of evidence which led the authors to develop the conceptual model shown in Figure 2. It was hoped that once the model had been developed, experimental treatments reported in the literature could be placed in cells of the matrix and that some consistent pattern of findings would emerge. Unfortunately, this desirable outcome did not materialize. In some cases it was possible to determine the matrix cell into which some experimental treatments fit. For example, the Tallmadge et al. (1968) inductive method used for teaching the Transportation Technique was found to be comparable to the direct reference method used by Kersh (1958), the guided discovery method used by Kersh (1962), and the directed discovery method used by Ray (1961). All of these instructional methods fit in Cell #2 of the Figure 2 matrix. In other cases, however, this type of sorting was not possible. Even after discussions with the author, it was not possible to determine whether the expository-deductive treatment employed by Tanner (1968) should properly be assigned to Cell #1 or Cell #3. Similarly, it could not be determined whether his inductive-discovery treatment fell into Cell #2 or Cell #4. In another instance, Hendrix (1947) employed an "unverbalized awareness" treatment which at first appeared to be comparable to Kersh's (1958) no-help method. Both instructional methods were inductive in nature, but further examination revealed an important difference between the two approaches. Kersh told Ss that they were to find the "rule" while Hendrix did not. Thus the two methods, though similar, were not strictly comparable. Neither of them, furthermore, could be assigned to one of the cells in the Figure 2 matrix with any degree of confidence.

There does appear to be some indication that, with respect to rote kinds of learning, an expository-deductive method of instruction may be superior to an inductive-discovery approach. Even this generalization, however, must be seriously questioned in the light of findings reported by Tallmadge et al. (1968). Although this study found the expository-deductive approach to be superior on an overall basis, the inductive-discovery approach was clearly superior for some types of learners.

Other studies have also found that interactions between learner characteristics and instructional treatment conditions were larger than overall effectiveness differences between the treatments. Snow, Tiffin, and

Seibert (1965), for example, found disordinal interactions involving certain personality characteristics of learners and a live vs. a filmed method of presentation of physics demonstrations. Although this study does not appear to bear directly on the question of expository vs. discovery teaching approaches, there is some indication that the live demonstrations were more akin to what has been called inductive teaching than they were to expository or deductive methods. More directly relevant were the results reported by Tanner (1968). He found disordinal interactions between sex and instructional methods with expository methods producing better achievement for boys and discovery methods producing better performance for girls. If one can assume that the learning which resulted from Tanner's programmed courses in physical mechanics was of the rote variety, his results are in close agreement with those reported by Tallmadge et al. (1968) with respect to an aircraft recognition learning task.

Although the evidence at this point is far from conclusive, there is a growing conviction that some instructional methods are better for some people and others are better for other people. Snow (1968), for example, has stated that he believes any research concerned with instructional methods must include consideration of aptitude-treatment interactions in order to be of significant value. It should be pointed out that although Cronbach, Snow, and their colleagues at Stanford talk about aptitude-treatment interactions, they have broadened their definition of aptitude to include non-cognitive as well as cognitive learner characteristics. Cronbach (1966) in fact has said that "the interacting variables may have more to do with personality than with ability". This conclusion was also reached by Tallmadge et al. (1968) based on an analysis involving some fifteen cognitive measures, none of which interacted with instructional treatment conditions, and fourteen non-cognitive measures, the majority of which did produce significant interactions.

The dimension represented by learner characteristics has not been included in the Figure 2 matrix simply because there is not yet enough evidence to identify critical variables. Still, there is more evidence to support the fact that learner characteristics are important than can be assembled in support of either the subject matter or type of learning dimensions which have been included. The Tallmadge et al. (1968) study provided the first clear-cut evidence that these dimensions might be of importance. Other studies such as Tanner's (1968) and those reported by Sieber and Kameya (1968) and Taylor and Fox (1967) offer additional, although less direct, support. Based on this evidence, it can certainly be concluded that a need exists to consider these dimensions in the design of future research. The authors believe that subject matter and type of learning variables when coupled with learner "aptitudes" will ultimately provide answers to many questions which currently exist relative to instructional methods.

It is, of course, also true that further research in this field, if it is to be productive, must seek common reference points so that individual studies can be meaningfully compared. Cronbach (1968) has emphasized this need suggesting that independent variables in educational and psychological research should be reported on an absolute rather than a relative scale. This point is particularly meaningful with respect to learner characteristics where samples of Ss are divided into high and low groups regardless of the population from which they are drawn. Where significant population differences exist, this practice can only lead to confusion.

The kinds of problems that currently exist in the aptitude-instructional method research are not atypical of any new field of investigation. The time has come, however, when the needs for standards which enable comparisons to be made among the many studies currently being undertaken is of prime importance.

III. DEVELOPMENT OF STRATEGIES FOR TAILORING TRAINING DEVICE DESIGN AND/OR UTILIZATION TO INDIVIDUAL DIFFERENCES IN LEARNING STYLE

Members of the project staff made some effort during the three month contract period reported here to assess the practical implications of aptitude-treatment interaction research for the design and use of training devices. Because of time, manpower, and budgetary limitations, this activity was limited in scope. Useful insights were achieved, however, and some tentative decisions were reached regarding ways in which the effectiveness of multi-track training based on learning style differences might be evaluated.

A. Survey of Training Devices

Project personnel, through review of relevant publications, visits to military training activities, and discussions with training device "experts", attempted to identify types of training devices which would be suitable for use in multi-track training programs employing different instructional methods. Because the state of the art in learning style research is still primitive, two rather restrictive limitations had to be placed on what could be considered suitable devices.

It seemed necessary, first of all, to consider only devices which are used in conjunction with initial learning. This restriction immediately eliminated a very large number of devices since nearly all weapon system and maintenance trainers are used for proficiency development after the trainees have been exposed to a considerable amount of classroom instruction.

The second restriction eliminated what might be called "skill" trainers. This category includes such devices as aircraft simulators, target tracking and gunnery devices, etc. Although at least some of these devices are used in initial learning situations, they do not provide the kind of controlled learning situation which could be structured to implement distinctly different instructional methods.

Additional restrictions of a practical nature existed with specific reference to the research which has been proposed as a follow-on to the present contract. These restrictions are associated with the "size" of the learning task, the need to experiment with groups of trainees rather than individuals, the availability of devices for experimental work, and the economic considerations connected with possible requirements to modify existing hardware.

Unfortunately, time did not permit a thorough evaluation of large numbers of devices with respect to these restrictions. Further effort must be devoted to this task before any final selections are made. It has been determined, however, that at least some devices exist which appear to meet all requirements. Specific devices which have been tentatively identified are discussed below in conjunction with considerations regarding how they might be employed in experimental training situations.

B. Considerations for the Design of Experimental Training Programs

The recently completed experimental study in this series (Tallmadge et al., 1968) identified two different types of learners. One type of learner performed best on a logico-mathematical learning task when an inductive (guided discovery) instructional method was employed but was more successful on a visual discrimination learning task when deductive methods were used. The other type of learner performed best on the same learning tasks when the opposite instructional methods were used. Because this research was more or less of a laboratory type, it was originally felt that the most productive use of additional research expenditures would be to conduct an experimental demonstration program involving "real world" training situations and existing training devices. It was also hoped, of course, that this effort would serve to clarify some of the issues which the previous study left unresolved.

It is still planned that an experimental demonstration, involving real world training situations and existing training devices, will be conducted. New ideas and hypotheses have come to light, however, as a result of analyses conducted since completion of the last experimental phase of this research program. (These new developments are discussed in Section II of this report.) It may be possible to investigate some of these ideas and hypotheses in the next experimental phase without compromising the original intent.

When the results of the Tallmadge et al. (1968) study were re-examined in light of the conceptual model presented in Figure 2 (p. 10), it appeared that the two experimental versions of the logico-mathematical subject matter course fell into Cells 3 and 2 rather than 1 and 2. Thus, if the Figure 2 model is meaningful, type of learning rather than method of instruction may have produced the observed interaction with learner characteristics. This possibility needs to be investigated.

Ideally, then, experimental conditions should be set up which would enable comparisons to be made between Cells 1 and 2, 3 and 4, and 5 and 6 in the Figure 2 matrix. An experiment of this type would do much to clarify the many ambiguities discussed in Section II of this report. Until final selection of the subject matters to be taught and the training devices to be used has been made, it will not be possible to determine whether this can be accomplished. At the present time, however, it does not appear to be an unlikely possibility. If, for example, celestial navigation were chosen as a training topic and if Navy Training Device 1X4, a series of concentric spheres designed to illustrate the apparent movement of celestial bodies, were selected as an appropriate experimental vehicle, it would not require an inordinate amount of additional effort to prepare courses suitable for Cells 1 through 4 in the Figure 2 matrix. Since a similar problem would not arise with respect to the arbitrary rules subject matter topic, a total of six experimental courses would then be required as opposed to the originally proposed four. Further analysis of this possibility needs to be made, and further analysis is also required, as previously mentioned, before making a final decision regarding the course topics and training devices.

The research plans call for examining the use of training devices in the teaching of arbitrary rules topics as well as meaningful rules topics. Navy training subject matters which appear to satisfy the requirements for this type of investigation include "rules of the road", the semaphore alphabet, ship silhouette recognition, etc. Suitable devices have been found to exist in at least some of these areas, but a complete evaluation has not yet been made.

The majority of these devices are designed for individual rather than group use. This feature makes the control of instructional method variables somewhat more difficult than is the case with classroom devices. Device 1H2A, a rules of the road trainer, appears to possess most of the desired characteristics, however, and may be selected if further investigation fails to uncover a suitable classroom type of device.

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